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Permanent post-concussion symptoms after mild head injury

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Abstract

Objective: A small minority of individuals experience long-term or permanent post-concussion symptoms (PCS) after a mild head injury (MHI). There has been no systematic, quantitative research examining a wide range of variables in a representative sample of such patients (i.e. with PCS for more than 18 months). This study explores a broad spectrum of demographic, cognitive, emotional and psychosocial factors (known to be important in the development of early PCS) in a representative sample of patients with permanent PCS.

Method: One hundred consecutively referred patients to a Community Head Injury Service in Buckinghamshire, UK for the treatment of persistent PCS, at least 18 months post-MHI, were identified and invited to participate. An exploratory design evaluated a range of demographic, cognitive, emotional and psychosocial variables and their relationship to PCS severity and quality-of-life (QoL).

Results: Twenty-four participants, with a mean time post-injury of 6.9 years, responded. They were characterized by: (i) older age compared to those typically presenting with MHI, (ii) very high levels of PCS, (iii) high post-injury unemployment, (iv) pre- or post-morbid factors which might exacerbate post-concussional difficulties, (v) elevated levels of anxiety and depression and (vi) mildly reduced scores on tests of short-term memory and speed of information processing. Post-hoc analysis of the total sample ($n = 100$) confirmed older age and a high proportion having pre- or post-morbid factors. QoL negatively correlated with PCS severity, and anxiety scores accounted for 45.9% of the variance in PCS severity.

Conclusions: Very high levels of PCS, high post-injury unemployment and measurable cognitive deficits can be permanent features of MHI. Quality-of-life is directly related to symptom severity. Age, pre-/post-morbid concomitant factors, neuropsychological deficits and emotional status are key variables in understanding the phenomenon of permanent PCS. Important vulnerability factors in the development of such may therefore be older age and any additional compromise to an individual's emotional or cognitive capacities.

Keywords: *Mild head injury, permanent post-concussion symptoms*

Introduction

The incidence of head injury in industrialized countries is high [1]. The vast majority of such injuries result in post-traumatic amnesia (PTA) of less than 24 hours. Historically these have been termed 'mild' and 'moderate' injuries (for PTA < 1 hour and 1–24 hours, respectively). More recent taxonomies, however, have classified all injuries with a PTA of less than 24 hours as 'mild head injury' (MHI) [2]. A very wide range of clinicians will regularly see these patients and approximately half of those with MHI will be affected by a cluster of cognitive, somatic and emotional symptoms for some duration [3]. These are normally termed 'post-concussion symptoms' (PCS) or seen as the constituent symptoms of 'post-concussion syndrome'.

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They include headaches, dizziness, fatigue, irritability, reduced concentration, sleep disturbance, memory dysfunction, sensitivity to noise or light, double or blurred vision, nausea, anxiety and depression [4]. They are conceptualized as being caused by organic and/or psychological mechanisms. Complete resolution of such symptoms normally occurs within 3 months of the injury and for many within the first few days or weeks. Twenty-to-forty per cent may, however, continue to experience PCS at 6 months post-injury [5] and a small minority still have difficulties at 1 year and beyond [6]. In the latter, PCS can be defined as being 'long-term' or 'permanent'.

Almost all MHI studies to date have focused on the early presentation and development of PCS. They have investigated a range of demographic, cognitive and psychosocial variables, usually up to 6 months post-injury. Some of the most important findings have included: (i) anxiety levels, soon after MHI best predict PCS severity at 6 months post-injury [7]; (ii) early psychological intervention after MHI reduces PCS severity at 6 months post-injury [8]; (iii) short-term memory and speed of information processing deficits are common in the early stages after MHI [9]; and (iv) speed of information processing deficits often mirror PCS severity and recovery up to 6 months post-injury [10]. Studies have also identified predisposing factors to experiencing more severe or longer lasting PCS. These include; (i) being over the age of 40 [11, 12]; (ii) being female [12, 13]; (iii) sustaining previous MHIs [12, 14]; (iv) having pre- or post-morbid psychopathology or substance misuse [15]; and (v) pursuing a compensation claim [16]. Few studies have investigated PCS beyond 1 year, even though long-term symptoms can cause very significant psychosocial and occupational difficulties. Those that have, have not used quantitative methods and investigated a wide range of variables or accessed representative samples of this group of patients. Such findings, therefore, shed only very limited light on the phenomenon of permanent PCS.

The current study is the first, to the authors' knowledge, to use quantitative methods to examine a wide range of variables in a representative sample of individuals living with PCS at least 18 months following MHI. It investigates a range of demographic, cognitive and psychosocial factors, known to be important in the early development of PCS, and examines their relationship with long-term PCS. It uses an exploratory design to identify whether any of these factors are particularly characteristic of this group of individuals and which variables have the strongest relationships with severity of long-term PCS and quality-of-life.

Method

All patients referred to the Community Head Injury Service (CHIS) in Buckinghamshire, UK for the treatment of persisting PCS following a MHI between 1997–2008 were identified from clinical records. The Community Head Injury Service provides community-based neurorehabilitation to all referred head injured patients of all severities (mild, moderate, severe and very severe) in Buckinghamshire. It serves a mixed rural and urban population of ~725 000 and its referrals come from a wide range of community sources—predominantly from GPs and Brain Injury Clinical Nurse Specialists, but also from self or family referrals, Neurologists, social services or other clinicians. Referrals are therefore likely to be as representative of this group of permanent PCS patients as possible. Participants were required to have sustained a MHI at least 18 months prior to the study. *The Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine* [2] definition of MHI was used, i.e. a head injury resulting in; PTA of less than 24 hours, GCS between 13–15 and no inter- or intra-cerebral complications. They were also required to have at least three current PCS (as assessed by the Rivermead Post-Concussion Symptoms Questionnaire (RPQ) [17]) because both DSM-IV and ICD-10 require at least three PCS to be present for the diagnostic criteria for 'post-concussion syndrome' to be met. This ensured that the population accurately reflected those with permanent PCS. It should be acknowledged, however, that if large numbers of participants were excluded on this basis then the PCS severity of the cohort could have been artificially inflated. Ultimately none of them had less than three symptoms and so all met the criteria for 'post-concussion syndrome' while not biasing the sample.

Individuals were excluded from the study if they had any history prior to or following MHI of a severe head injury, substance/alcohol dependence or other neurological conditions. Further exclusion criteria included any prior history of other medical or psychological conditions likely to substantially account for post-concussional type symptoms, e.g. severe and chronic pain, severe depression. Examination of the clinical records determined whether participants fulfilled these criteria. Missing GCS data was the primary omission in the notes and one consenting participant did not have details of their PTA recorded. In the former cases a GCS of 13–15 was assumed on the basis of a PTA less than 24 hours and in the latter case the converse was assumed. Ethical approval for the study was obtained.

One hundred individuals were identified as eligible and invited to take part by letter which included an RPQ to complete. Thirty individuals consented (all

of whom had at least three current PCS). Six withdrew prior to testing. Reasons for withdrawal included anxiety regarding cognitive assessment and current illnesses of another nature. The sample was therefore 24 participants. This response rate is very similar to other studies of MHI patients some years after their injury [18]. It is slightly lower, however, than at least one study which achieved an overall rate of just under 50% [19].

Procedure

Consenting participants were initially sent five questionnaires to complete by post. The questionnaires measured severity of PCS (RPQ), quality-of-life (World Health Organization Quality of Life Measure (WHO-QoL)) [20], anxiety/depression symptoms (Hospital Anxiety and Depression Scale (HADS)) [21], post-traumatic stress symptoms (Impact of Event Scale Revised (IES-R)) [22] and pain levels (McGill Pain Questionnaire) [23]. Participants were encouraged to pace completion of the questionnaires so as to not be affected by fatigue. Soon after sending the questionnaires, participants were contacted by telephone to arrange a mutually convenient time and location to conduct the cognitive assessments. Eleven cognitive tests were administered which measured a range of domains—verbal and visuo-spatial short-term and long-term memory (BIRT Memory and Information Processing Battery (BMIPB) Story Recall and Figure Recall tests), verbal rate of learning (BMIPB List Learning Test), executive functioning (Controlled Oral Word Association Test (COWAT), Stroop Test (from the Delis–Kaplan Executive Function Scale (DKEFS) and Trail Making Test (from DKEFS)), pre-morbid and current intellectual functioning (National Adult Reading Test (NART)), speed of information processing (Paced Auditory Serial Addition Task (PASAT) and BMIPB Speed of Information Processing Test), passive and active auditory attention spans (WAIS III Forward and Backward Digit Spans) and effort (Green Word Memory Test (GWMT)). Assessments took place either in the participant's home or at the Community Head Injury Service. The administration order was consistent across all participants. All 24 participants were able to complete all, or the vast majority of the cognitive assessments, i.e. there was a zero drop out rate for those who consented to be tested.

Results

Sample characteristics

The sex ratio of the 24 participants was 50% male to 50% female. The ratio of the 76 non-participants was 62% to 38%. This was not significant ($p < 0.05$). The mean PTA for participants and non-participants was 157 minutes (SD = 340.1) and 301 minutes (SD = 498.9), respectively. This was not significant ($p < 0.05$). One participant and 11 non-participants had missing PTA data. All of these, however, had a GCS of 15 and/or loss of consciousness of less than 2 minutes. There was insufficient data to compare GCS scores. The mean age of participants and non-participants at the time of their MHI was 44.7 (SD = 8.8) and 38.6 (SD = 11.9), respectively. This was not significant at $p < 0.01$, but was at $p < 0.05$ ($t = 2.33$, df = 98). There were, therefore, no significant differences between the participant and non-participant groups, except for the possibility that the latter were slightly younger than the former.

PCS severity

The mean severity of PCS, as measured by the RPQ, was 34.5 (SD = 10.6, $n = 24$). This dependent variable was normally distributed. There are no agreed clinical cut-offs for the RPQ, but a score of 34–35 represents approximately eight symptoms causing 'a severe problem' or 12 causing 'a 'moderate problem'. It compares with mean RPQ scores of 7–8 in a large representative sample of MHI patients seen at 6 months post-injury in the neighbouring county of Oxfordshire ($n = 478$) [24]. Oxfordshire has a similar mixed rural and urban population to Buckinghamshire and is a similar size (~600 000). Only 4% of this sample had scores greater than 33.

Demographics

Descriptive data were used to assess the demographic characteristics of the sample. Table I provides frequency counts for categorical demographic variables.

The mean age of participants at the time of their MHI was 44.7 years (SD = 8.8) with a range of 34 years (min = 30, max = 64). Nearly 70% of the sample was aged over 40 years, with the remaining 30% ranging between 30–40 years of age. The mean ages of the sample ($n = 24$) and the sample as a whole ($n = 100$) were significantly higher than the representative sample of MHI patients in Oxfordshire seen at 7–10 days post-injury ($n = 1156$) ($p < 0.001$) ($t = 5.51$, df = 1178 and $t = 7.47$, df = 1254, respectively), where the mean age was 30 (SD = 13) (and where only 30% were aged 40 or over and 60% were under the age of 30) [24].

The mean time post-injury was 83.7 months (SD = 47.6), i.e. 6.9 years, with a range of 178 months (min = 24, max = 202). There was no relationship between age and severity of PCS ($r = -0.014$, $n = 24$, $p = 0.949$) or between time

Table I. Demographic characteristics of the sample.

Demographic variable	Variable level	*n*	Proportion of sample (%)
Gender	Male	12	50.0
	Female	12	50.0
Pre-MHI marital status	Married/co-habiting	19	79.2
	Single	2	8.3
	Divorced/bereaved	3	12.5
Post-MHI marital status	Married/co-habiting	14	58.3
	Single	2	16.7
	Divorced/bereaved	8	33.3
Dependent others	Present	11	45.8
	Not present	13	54.2
Pre-MHI employment	Employed	22	91.7
	Unemployed	1	4.2
	Sick leave	0	0.0
	Retired	1	4.2
Post-MHI employment	Employed	12	50.0
	Unemployed	7	29.2
	Sick leave	3	12.5
	Retired	2	8.3
Education	No qualifications	1	4.2
	Secondary school	9	37.5
	College	3	12.5
	University	11	45.8
MHI causation	Domestic/leisure/work accident	4	16.7
	Road traffic accident	13	54.2
	Sports	1	4.2
	Assault	6	25.0
Compensation claim	No claim	6	25.0
	Incomplete claim	5	20.8
	Complete claim	13	54.2
Peri-MHI serious injury/illness	Present	12	50.0
	Not present	12	50.0
Post-MHI serious injury/illness	Present	6	25.0
	Not present	18	75.0
Previous head injury	Present	2	8.3
	Not present	22	91.7
Pre-MHI psychological difficulties	Present	7	29.2
	Not present	17	70.8
Post-MHI psychological difficulties	Present	10	41.7
	Not present	14	58.3
Post-MHI significant life event	Present	18	75.0
	Not present	6	25.0

since injury and severity of symptoms ($r = -0.170$, $n = 24$, $p = 0.428$). The mean duration of PTA was 157 minutes (SD = 340.1), with a range of 1440 minutes (min = 0, max = 1440). There was no relationship between PTA and severity of PCS ($r = -0.104$, $n = 23$, $p = 0.683$).

Half the sample was male and half was female. This compares with male-to-female ratios of 66%:38% and 74%:26% in two representative Oxfordshire samples of MHI patients ($n = 1156$ and $n = 314$, respectively) [8, 24]. The former is not significantly different to the present sample, but the latter is ($p < 0.05$) and suggests that females may have been over-represented in the current cohort.

Approximately 92% were actively employed pre-injury compared to 50% at the time of the study. Only a small proportion of this decline was due to retirement (4.1%). Over half the sample had completed a compensation claim and ~20% continued to pursue a claim. The majority sustained their MHI as the result of a road traffic accident (54.2%) or assault (25%). This is approximately twice as high as the Oxfordshire sample at 6 months post-injury (25.7% and 12.8%, respectively).

Fifty per cent sustained a serious injury alongside their MHI, 29.2% had experienced psychological difficulties at some point prior to their MHI and 41.7% experienced psychological difficulties after their MHI; 76% endorsed some form of pain on the McGill Pain Questionnaire. A post-hoc review of the case notes of the total sample ($n = 100$) revealed that only 3% of those with persisting symptoms had no

Table II. Performance on cognitive measures.

Cognitive measure	*n*	Mean raw score (SD)	Mean *T* value (SD)	Percentile range* (classification)**	Pearson's *r* with PCS severity (*p*)
NART predicted full scale IQ	22	108.4 (8.5)	NA	69th–71st (Av)	−0.333 (0.130)
List learning total	23	47.3 (10.0)	44.4 (9.5)	27th–29th (Av)	−0.411 (0.051)
Story recall (immediate)	24	24.9 (10.4)	44.5 (11.0)	27th–29th (Av)	−0.231 (0.279)
Story recall (delayed)	24	22.0 (10.0)	47.7 (10.3)	40th–42nd (Av)	−0.169 (0.431)
Story recall (retained; %)	24	87.5 (12.9)	50.5 (7.5)	52nd (Av)	−0.024 (0.913)
Figure copy	24	76.5 (3.2)	47.7 (8.2)	40th–42nd (Av)	−0.419 (0.041)
Figure recall (immediate)	24	53.1 (16.2)	44.8 (12.0)	29th–31st (Av)	−0.173 (0.418)
Figure recall (delayed)	24	51.9 (15.9)	49.6 (10.0)	48th–50th (Av)	−0.380 (0.067)
Figure recall (retained; %)	24	100 (22.8)	56.1 (8.4)	72nd–74th (Av)	−0.428 (0.037)
Speed of Info. Processing	24	63.4 (16.7)	40.5 (7.1)	17th (LAv)	−0.199 (0.352)
PASAT correct (2.4 s trial)	22	40.7 (13.6)	43.5 (20.4)	25th–27th (Av)	−0.406 (0.061)
PASAT correct (2.0 s trial)	21	39.6 (10.0)	49.5 (14.3)	48th (Av)	−0.556 (0.009)#
PASAT correct (1.6 s trial)	21	32.8 (10.3)	51.0 (12.9)	54th (Av)	−0.528 (0.014)
PASAT correct (1.2 s trial)	19	26.5 (7.9)	59.1 (15.8)	81st–83rd (HAv)	−0.746 (0.000)#
Digit span forward	24	5.8 (1.2)	44.6 (8.9)	29th–31st (Av)	−0.194 (0.363)
Digit span backward	24	4.0 (1.3)	44.8 (9.2)	29th–31st (Av)	0.127 (0.554)
Digit span difference	24	1.8 (1.4)	50.1 (10.5)	50th–52nd (Av)	−0.292 (0.167)
COWAT Letter fluency	23	48.7 (9.9)	57.0 (8.4)	75th–77th (HAv)	−0.594 (0.003)#
Trail making part A (s)	20	35.9 (8.8)	52.9 (7.6)	60th–62nd (Av)	0.208 (0.380)
Trailing making part B (s)	19	78.6 (32.5)	59.3 (19.9)	81st–83rd (HAv)	0.068 (0.783)
Stroop (s)	23	63.0 (15.9)	48.1 (10.8)	42nd–44th (Av)	0.337 (0.116)
Stroop plus switching (s)	23	67.0 (17.8)	51.2 (9.2)	54th–56th (Av)	0.264 (0.223)

*Percentile range based on *T*-value.
**Classification of percentile range: Impaired (I), Borderline impaired (B), Low average (LAv), Average (Av), High average (HAv), Superior (S), Very superior (VS).
#Significant correlation ($p < 0.01$) with PCS severity as measured by the RPQ.

concomitant factors, 4% had equivocal concomitant factors (e.g. anxiety probably related to dealing with PCS or concurrent life stressors), 40% had documented pre-morbid problems at some point prior to their MHI (predominantly depression, anxiety, pain or post-traumatic stress symptoms) and 59% had documented post-morbid problems unlikely to be caused directly by their response to PCS (predominantly driving anxiety, post-traumatic stress symptoms, pain or severe anxiety/depression).

There were no significant correlations between scores on the RPQ and any of the demographic measures listed below.

Cognitive factors

Table II provides descriptive statistics and standard scores for all cognitive variables. The results of the cognitive assessments indicated a general trend of average performance across all cognitive variables. The mean predicted Full Scale IQ from the NART lay in the 69th–71st percentile range, reflecting the upper end of the average range

The sample scored in the low average range on the BMIPB Speed of Information Processing task. In addition, the sample scored on the border of the low average to average ranges for the slowest trial of the PASAT (2.4 second trial). These results suggest some level of difficulty in information processing speed across visual and auditory modalities. Interestingly, the sample scored in the high average range for the fastest trial of the PASAT—a result most likely due to drop-out on the task after the initial trial. Despite this artefact, Table II indicates that the PASAT (2.0 and 1.2 second trials) was significantly and negatively correlated to the severity of PCS as measured by the RPQ. Performance on the COWAT was also negatively correlated with PCS severity. The sample scored at the very bottom of the average range on the BMIPB List Learning, Story Recall (Immediate) and Figure Recall (Immediate) tasks. These measures did not correlate significantly with RPQ scores, indicating reduced ability irrespective of symptom severity.

Emotional factors

Table III provides results from measures of emotional functioning. The results indicate that mean scores of both anxiety and depression met the clinical case cut-off criteria. The mean Impact of Event Scale Revised score similarly met clinical case criteria.

In addition, Table III provides frequency data regarding potentially diagnosable psychological difficulties as determined by clinical case cut-off scores from standardized data of the respective psychometric assessments. It appears that the majority of

Table III. Pearson's correlations on measures of emotional sequelae.

Measure	*n*	Mean score (SD)	Participants in clinical range (%)	Pearson's *r* with PCS severity (*p*)
Hospital Anxiety and Depression Scale (anxiety scale; clinical cut-off ≥ 8)	23	11.43 (4.3)	19 (79.2)	0.695 (0.000)*
Hospital Anxiety and Depression Scale (depression scale; clinical cut-off ≥ 8)	23	9.9 (4.9)	15 (62.5)	0.398 (0.060)
Impact of Event Scale-Revised (clinical cut-off ≥ 26)	21	31.0 (19.8)	11 (52.4)	0.159 (0.490)

*Correlation significant at the $p < 0.01$ level, two-tailed.

Table IV. Pearson's correlations on quality-of-life measures.

$n = 24$	Pearson's correlation (*r*)	*p*
WHO QoL–physical	−0.622	0.001*
WHO QoL–psychological	−0.520	0.009*
WHO QoL–social	−0.306	0.146
WHO QoL–environmental	−0.578	0.003*

*Correlation significant at the $p < 0.01$ level, two-tailed.

Table V. Independent variables significantly related to RPQ scores.

Variable	*n*	Pearson's correlation	*p* (two-tailed)
HADS Anxiety sub-scale	23	0.695	<0.01
COWAT Letter Fluency	23	−0.594	<0.001

Table VI. Step-wise multiple regression model.

Model	Unstandardized coefficients		Standardised coefficients		
	B	SE	Beta	*t*	*p*
(constant)	13.974	4.962		2.82	0.011
HADS Anxiety	1.298	0.406	5.13	3.20	0.005
COWAT Letter Fluency	−0.448	0.180	−0.400	−2.49	0.022

individuals in the sample experienced levels of anxiety and depression indicative of clinical concern. Just over half the sample experienced significant post-traumatic stress type symptoms. From inspection of individual IES-R forms, however, this appeared to be predominantly an artefact of high scores on items which reflect general symptoms of anxiety (e.g. increased vigilance) rather than symptoms specifically related to post-traumatic stress disorder (e.g. re-experiencing phenomena).

There was no significant relationship between the presence of pain and RPQ scores.

Psychosocial factors

The mean WHO-QoL total score was 213.9 ($SD = 57.3$, $n = 24$). Whilst normative data for the WHO-QoL is not available, a Pearson's correlation indicated a significant and negative relationship between the quality-of-life and severity of PCS as measured by the RPQ ($r = -0.596$, $n = 24$, $p < 0.05$, one-tailed). As such, quality-of-life decreases with increasing severity of PCS. When explored further, the severity of PCS significantly and negatively correlated with all but one sub-scale of quality-of-life as assessed by the WHO-QoL (Table IV).

Regression analysis

Due to a small sample size relative to a large range of variables employed it was inappropriate to apply an adjusted threshold of significance as determined by Bonferroni correction to correlational analyses. The results should therefore be interpreted with caution regarding Type 1 errors. In an attempt to reduce these errors, the threshold of significant probability was set at $p < 0.01$.

Correlational analyses were conducted to determine which cognitive, demographic and psychosocial factors significantly correlated with the dependent variable. Pearson's regression was applied to test correlational significance between variables of continuous data. Mann Whitney Tests were performed with non-normally distributed categorical variables. All independent variables that demonstrated a significant relationship with the dependent variable were extrapolated (Table V) and used in a step-wise linear regression analyses.

The model which emerged (Table VI) accounted for 57.1% of the variance ($r^2_{adj} = 0.571$) and significantly predicted severity of PCS ($F_{2,20} = 14.956$, $p < 0.01$). The regression analysis indicated that

anxiety, as measured by the HADS, accounted for 45.9% of variance in severity of PCS. Performance on the COWAT Letter Fluency task accounted for 11.2% of the variance.

Discussion

The current study is the first systematic, quantitative investigation of a representative sample of individuals with long-term PCS, across a range of demographic, cognitive, emotional and psychosocial variables. The mean time post-MHI was nearly 7 years and the severity of PCS was very high (mean RPQ score = 34.5). The latter represents approximately eight PCS of 'a severe problem' or 12 of 'a moderate problem'. It contrasts with mean scores of 7–8 at 6 months post-injury in a large representative group of MHI patients at 6 months post-injury ($n = 478$) in the neighbouring county of Oxfordshire, which has a similar population [24]. This suggests that at least some individuals can experience highly significant PCS on a permanent basis following a MHI. Indeed the negative relationship between PCS severity and quality-of-life measures suggests that a MHI can have a substantial and permanent impact not only at the level of impairment, but also at the levels of activity and participation (WHO Model of Illness [25]). This is supported by the high levels of post-injury unemployment. Approximately 92% of the sample was actively employed at the time of their MHI and only 50% at follow-up (with just a small proportion of this decline being accounted for by retirement).

Clinically, cognitive deficits can be determined by performances under 1 SD from an expected score (e.g. as indicated by measures of predicted premorbid levels of intellectual ability, such as the NART). The mean predicted Full Scale IQ of the current sample was 108.4, reflecting the 69th–71st percentile range—classified as the higher end of the average range. Based on mean standard scores (i.e. *t*-values) the current findings indicate mild deficits on two measures of speed of information processing (BMIPB Speed of Information Processing Test and PASAT slowest trial). The most consistent results in neuropsychological studies of early PCS indicate negative correlations of speed of information processing with severity of symptoms. The current study supports previous findings in that at least some measures of such were negatively associated with permanent PCS severity. These measures were unable, however, to account for significant amounts of variance in symptoms in a predictive model of the sample. The current study also identified below expected performances on measures of verbal rate of learning (BMIPB List learning test), verbal short-term memory (BMIPB Story test) and visuo-spatial short-term memory (BMIPB Figure test). Deficits in short-term and long-term memory, for both verbal and visuo-spatial material, are a feature of individuals with early PCS. The current study, therefore, provides support for the persistence of verbal and visuo-spatial short-term memory difficulties in those with long-term PCS, but not long-term memory deficits.

The older mean age of the current sample (44.2 years), compared to a large representative sample of MHI patients in Oxfordshire (30 years) supports previous findings that PCS are more prevalent and longer lasting among individuals over 40 years of age. It extends this finding, however, by indicating that permanent PCS may be much more likely in older patients. Whilst by no means unequivocal, it also lends support to the idea that organic processes may continue to operate in at least some of those with long-term symptoms—in that there is no reason to expect increasing psychological mechanisms operating with age but some reason to expect less complete organic recovery with increasing age. The very high proportion of participants with concomitant problems (either pre-morbidly or post-morbidly), alongside the negative relationship between PCS severity and some measures of speed of information processing, suggests that a further vulnerability to developing permanent PCS may be the presence of any additional compromise to the cognitive or emotional capacity of individuals.

The current findings corroborate the high prevalence of anxiety and depression in those with persisting PCS with ~80% and 63% of participants meeting clinical cut-off on the HADS for anxiety and depression, respectively. Whilst measures of anxiety correlated highly with PCS severity, measures of depression and post-traumatic stress symptoms did not. Anxiety is associated with the severity of PCS at 3 months, 6 months and 12 months post-MHI [7, 24] and the current findings support such findings for long-term PCS, in that anxiety accounted for 45.9% of variance of PCS severity. Unfortunately the current data do not help clarify the exact role of anxiety in those with permanent symptoms. It is possible that anxiety is the entirely normal response to a very disabling set of organic symptoms, primarily manifested as reduced speed of information processing. Indeed the emotional distress caused by the chronic and unsuccessful attempts to manage speed of information processing deficits after a MHI has been termed the 'coping hypothesis'. Equally the development of high levels of anxiety after a MHI may be the substantial contributor to the presentation of PCS as the vast majority of PCS type symptoms are identical to anxiety-based symptoms or those of others disorders

(e.g. depression, PTSD, chronic pain). Alternatively, the somatic symptoms inherent in 'PCS' may be predominantly due to the somatization of anxiety responses to a traumatic event. Sigurdardottir et al. [26] for example found that somatic items on the RPQ were the strongest predictor of overall symptom severity at 1 year post-injury. In addition, somatic symptoms were associated with high levels of anxiety. It is therefore possible that, for some individuals, at a certain point following MHI, anxiety and trauma-type symptoms become expressed as somatic symptoms of post-concussion. Whilst it is therefore clear that anxiety can play an important role in long-term PCS it is still far from clear in what way it operates.

The main limitations of the study are its relatively small sample size and its exploratory, uncontrolled design. A sample of 24 means that a degree of caution should be exercised regarding the conclusions drawn. The employment of a prospective, controlled design with a larger sample would significantly strengthen its findings.

Conclusions

PCS can be both highly disabling and permanent. The current study demonstrates that these long-term problems are associated with measurable cognitive deficits, older age, high levels of anxiety, high post-injury unemployment and pre-/post-morbid concomitant difficulties. The role of anxiety is important, but its mechanism is not clear. The older age of the current sample suggests that organic factors may continue to operate for some patients, but neuropsychological and emotional variables are clearly also important. The high numbers with concomitant factors and the negative correlation between speed of information processing deficits and PCS severity suggests that those with additional compromises to their cognitive or emotional capacities may also be more susceptible to long-term difficulties.

The study demonstrates the appropriateness of understanding permanent PCS in the context of a biopsychosocial model and future research might focus on models from other areas of the clinical literature which could clarify the mechanisms which perpetuate symptoms. Models of other difficult-to-explain long-term conditions, such as chronic pain and chronic fatigue, might be particularly helpful.

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