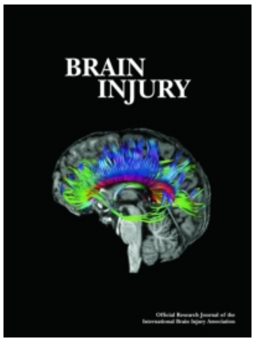

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Rating of pre-injury symptoms over time in patients with mild traumatic brain injury: the good-old-days bias revisited

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ABSTRACT

Objective: Post-concussion syndrome (PCS) occurs following mild traumatic brain injury (mTBI). Patients with mTBI are often assessed using self-report instruments that rely on perception of current symptoms compared to how they felt and functioned pre-injury. The objective was to examine reliability of patients' post-injury reporting of their pre-injury symptoms.
Methods: We included two control groups (trauma patients without brain injury history and healthy controls) who were recruited at an outpatient surgical clinic and among the working and social environment of the researchers, respectively. The Head Injury Symptom Checklist (HISC) was used to assess pre-injury and current symptoms at four time points post injury. We included 836 patients with mTBIs, 191 trauma patients without brain injury history, and 100 healthy controls.
Results: Patients with mTBI reported significantly more pre-injury symptoms than both control groups ($p < .001$). Forty-five percent of patients with mTBI were inconsistent in their pre-injury ratings across four assessments. Patients with post-injury PCS reported much greater pre-injury symptoms and were more often inconsistent.
Conclusion: Accurately assessing PCS by comparing pre with post-injury complaints is difficult, and may have implications for diagnosis when using self-report instruments. Therefore, post-injury PCS diagnosis should be interpreted with caution and PCS should ideally be examined using clinical examination.

KEYWORDS
Traumatic brain injury; post-concussion symptom; post-concussion syndrome; good-old-days bias

Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability worldwide and half of the world's population will experience one or more TBIs over their lifetime (1). The large majority of TBIs (70–90%) can be classified as mild (mTBI) (1), which is often indicated by a Glasgow Coma Scale (GCS) score between 13 and 15 at admission to the emergency department. Most patients report complete symptom resolution following mTBI (2,3); however, a subset of patients report post-concussion symptoms, which can be defined as somatic, cognitive, and emotional symptoms that may last for months or even years (4–6). When three or more post-concussion symptom categories are present, a patient can be diagnosed with 'postconcussional syndrome' (PCS) according to the definition by the International Classification of Diseases (ICD)-10 (7). The diagnosis of PCS is highly controversial because symptoms do not always cluster in a consistent and predictable manner (8). In addition, post-concussion symptoms, such as fatigue, concentration difficulties, and headaches, are not specific to TBI and are also reported among trauma patients without brain injury history (9–11) and healthy adults (12,13). The method of assessment of post-concussion symptoms and PCS, such as using a clinical interview versus a self-reported questionnaire, is another topic of controversy (14,15). Nevertheless, post-concussion symptoms are generally examined with self-report questionnaires.

The use of self-report may have several limitations in a mTBI population, because symptom endorsement on self-report questionnaires might be influenced by expectation bias; i.e. following mTBI, patients may expect that they will experience some post-concussion symptoms and may therefore be more likely to endorse these symptoms (16). Additionally, it might be difficult to make a distinction between the two, considering PCS could also be a part of or a result from emotional distress, which commonly occurs in the aftermath of TBI (10,17,18). Furthermore, some self-report instruments (e.g., the Rivermead post-concussion questionnaire (RPQ) (19)) investigate a comparison of current symptoms with symptoms experienced before injury. The reliability and validity of pre-injury symptom ratings might be complicated because patients may not remember symptoms that occurred months earlier in an accurate manner (20). Moreover, following a negative event, patients may have the tendency to underestimate past problems and to view oneself as healthier in the past, which is referred to as

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the 'good-old-days' bias (21). Previous studies examined the occurrence of the 'good-old-days bias' in patients with mTBI (20–24). They consistently found that patients with mTBI remembered their pre-injury functioning as better compared to healthy controls. As a consequence of this cognitive bias, patients may misattribute the experience of common symptoms to the mTBI, and thereby increase the possibility of an incorrect PCS diagnosis (25). These previous studies assessing the reliability and validity of pre-injury symptom ratings are, however, limited by small sample sizes (20,23,24) and the use of non-representative patient groups (21,22). In addition, previous studies assessed the pre-injury symptom-level only once or twice (24), whereas repeated measurements may provide further insight into the test-retest reliability of pre-injury ratings. Especially since test-retest reliability was noted as less than optimal for most common and emerging concussion assessment tools (26,27).

This study aimed to assess the reliability and validity of post-injury ratings of symptoms compared with pre-injury symptoms in a large and representative sample of patients with mTBI at several time points during the first year following injury. Additionally, these ratings of patients with mTBI were compared to both trauma patients without brain injury history and healthy controls. We specifically tested the three hypotheses, based on previous research and clinical experience, listed below.

(1) Both patients with mTBI and trauma patients without brain injury history will underestimate their pre-injury symptom level (i.e., 'good-old-days bias') by reporting fewer symptoms than healthy controls.
(2) The consistency (i.e., test-retest reliability (28)) of ratings of pre-injury symptoms at different time points will be low in patients with mTBI.
(3) Patients with mTBI who have post-injury PCS will be more likely to underestimate their pre-injury symptoms and will be less consistent in their ratings compared to patients with mTBI without post-injury PCS.

Methods

Study population

Data from patients with mTBI were obtained from the prospective UPFRONT study, which collected baseline, clinical, and outcome data across three level I trauma centers in the Netherlands between 2013 and 2015 (29). Patients were included if they presented to the emergency department of one of the participating centers with an admission GCS score of 13–15.

Trauma patients without brain injury history were recruited at the outpatient surgical clinic of the University Medical Center Groningen between June and October 2013. Patients were included if they sustained minor injury to one of the extremities, for which they had visited the emergency department. Patients were excluded if they completed the questionnaire more than six months (> 185 days) after the injury.

Healthy controls were recruited among the working and social environment of the investigators involved with the UPFRONT study. They were included if they were at least 16 years old and they had sufficient comprehension of the Dutch language. Patients were excluded if they were addicted to drugs or alcohol, homeless, or diagnosed with dementia. The study was approved by the medical ethics committee of the University Medical Center in Groningen and all participants provided written informed consent. For more information on the UPFRONT study or the study population, see previous publications (18,29,30).

Assessment of post-concussion symptoms and PCS

Post-concussion symptoms and PCS were assessed using the Head Injury Symptom Checklist (HISC) (18). The HISC consists of 21 frequently reported symptoms after a TBI, which can be rated on a 3-point scale (never, sometimes, often). Eight symptoms from the ICD-10 are included in the checklist: headache, dizziness, fatigue, irritability, sleep problems, concentration problems, memory problems, and intolerance of alcohol or stress. Stress intolerance is not a symptom included in the HISC, so for this we used the more anxious symptom. For each patient, we recorded the total number of ICD-10 symptoms endorsed as 'sometimes' or 'often'. In addition, we classified patients as having PCS if they indicated that at least three out of eight symptoms were experienced 'sometimes' or 'often'. Because it has not been established whether symptoms should be included if they are endorsed as 'sometimes' or only when they are endorsed as 'often' (31), we also estimated prevalence rates of post-concussion symptoms and PCS including only those symptoms that were endorsed as 'often'. For this study, we defined screening positively for ICD-10 PCS as endorsing any 3 of the 8 symptoms.

For patients with mTBI, the HISC was administered two weeks, three months, six months, and twelve months following injury. At each time period, patients were asked to rate both their current and pre-injury symptoms. The trauma patients without brain injury history completed the HISC once for both their current and pre-injury symptoms at approximately three weeks post injury. The healthy controls completed the HISC twice with a two-week interval and were asked to rate their current symptoms.

Statistical analyses

Baseline characteristics of patients with mTBI, trauma patients without brain injury history, and healthy controls were reported by frequencies and percentages, or medians and interquartile range for continuous variables. At each time point, we presented the number and percentage of participants who endorsed post-concussion symptoms and screened positively for the ICD-10 diagnosis of PCS, on both their retrospective pre-injury and current symptom ratings. Analyses were performed using SPSS statistics version 24.0.

Hypothesis 1: Both patients with mTBI and trauma patients without brain injury history *will underestimate their pre-injury symptom level (i.e., show the 'good-old-days bias') by* *reporting fewer post-concussion symptoms than healthy controls*. We used a chi-square test to compare the number of patients with three or more pre-injury post-concussion symptoms among patients with mTBI, trauma patients without brain injury history, and healthy controls. Non-parametric Kruskall-Wallis tests were used to compare the total number of ICD-10 symptoms across groups. For the patients with mTBI, we used the two-week assessment because this was most comparable to the assessment of the trauma patients without brain injury history (3 weeks). For the healthy controls we used their first rating (random selection). Post-hoc tests were performed to assess which of the three groups differed statistically significantly. A p-value of 0.02 (0.05/3) was considered statistically significant in the post-hoc analyses.

Hypothesis 2: The consistency (i.e., test-retest reliability) of pre-injury ratings will be low in patients with mTBI. We performed chi-square tests to compare the number of patients with three or more pre-injury post-concussion-like symptoms across all four time points (2 weeks, 3 months, 6 months, and 12 months) in patients with mTBI. Because this comprises six related comparisons, a p-value of 0.008 (0.05/6) was considered statistically significant. Spearman's correlation was used to compare the total number of ICD-10 symptoms across four time points. A correlation <0.5 can be interpreted as a weak correlation, a correlation 0.5–0.7 as a moderate correlation, and a correlation >0.7 as a high correlation. In addition, we calculated the number and percentage of patients with mTBI who consistently reported three or more symptoms over all four time points. Inconsistency was defined as reporting three or more symptoms on one or more of the pre-injury ratings but not on the preceding questionnaires. Multivariable logistic regression analysis was used to explore whether baseline characteristics and pre-injury comorbidities were predictive of inconsistency.

Hypothesis 3: Patients with mTBI who have post-injury PCS will be more likely to underestimate their pre-injury symptoms and will be less consistent in their ratings compared to patients with mTBI without post-injury PCS. We used the chi-square test to examine whether patients with and without PCS at six months differed on their pre-injury rating (also assessed at six months). The Mann-Whitney U test was used to examine whether the total number of pre-injury symptoms differed among patients with and without a diagnosis of PCS at six months post injury. Ratings at six months were chosen for this purpose because this is a common time point to evaluate persistent PCS. We additionally performed multivariable logistic regression analysis to adjust the effect of post-injury PCS diagnosis for age, sex, education, and pre-injury physical and psychological comorbidities. Patients were classified in the following four groups: persistent PCS (PCS present at two weeks and six months) (32), late-onset PCS (PCS not present at two weeks, but present at six months), resolved PCS (PCS present at two weeks, but not at six months), and no PCS (no PCS at both two weeks and six months). A chi-square test was performed to compare pre-injury ratings among these four groups.

To examine whether post-injury PCS was associated with inconsistency in pre-injury ratings, we used the chi-square test to check whether inconsistency (see hypothesis 2) was different for those with versus without PCS at six months. In addition, we also checked for differences between the four patient groups described above (no PCS, persistent PCS, late-onset PCS, and resolved PCS). Multivariable logistic regression analysis was performed to adjust the effect of post-injury PCS for age, sex, education, and pre-injury physical and psychological comorbidities.

Results

Study population

A total of 1,151 patients with mTBI were included in the UPFRONT study, of whom 836 completed either the retrospective pre-injury or the current rating of symptoms at two weeks post injury. Patients included in this study were older (46 years) than those who were not included (38 years). Patients' median age was 48 years (interquartile range (IQR): 27–62) and 61% were male. Patients were most often injured by a fall (n = 550, 66%) and the majority experienced loss of consciousness (n = 710, 85%) and/or posttraumatic amnesia (n = 682, 87%). A total of 509 patients (61%) were admitted to the hospital (Table 1).

The non-brain-injured trauma control group consisted of 206 patients, among whom 204 completed the HISC. Thirteen patients were excluded from the analyses because they completed the questionnaire more than six months (> 185 days) after the injury, which ultimately left 191 trauma patients without brain injury history. These patients had a median age of 35 years (IQR: 23–52) and 54.5% were male. Fall was the most common cause of injury (n = 92, 48.2%), and 35 patients (18.3%) were admitted to the hospital ward. The healthy control group consisted of 100 healthy volunteers, who all completed the HISC at two different time points. Healthy controls had a median age of 29 years (IQR: 24–48) and half of them were male. More than half of the healthy volunteers (n = 65, 65%) had a high education level (Table 1).

Post-concussion symptoms in mTBI and trauma patients without brain injury history during the first year post injury

Post-concussion symptoms were often endorsed among patients with mTBI during the first year post injury. Fatigue was the most commonly reported symptom at all time points (79% at 2 weeks, 66% at 3 months, 68% at 6 months, and 66% at 12 months). The majority of patients endorsed three or more out of eight post-concussion symptoms, and thereby fulfilled our criteria for the ICD-10 diagnosis of PCS (84% at 2 weeks, 72% at 2 months, 78% at 6 months, 75% at 12 months; Table 2). Among the trauma patients without brain injury history, 38% (n = 73) were classified as having PCS approximately three weeks post injury. The most often reported symptoms included sleep problems (n = 90, 47%) and fatigue (n = 84, 44%).

Including only those symptoms that were endorsed as 'often' rather than 'sometimes or often', resulted in substantially lower

Table 1. Characteristics of the study sample.

	Patients with mTBI (n = 836)*	Trauma patients without brain injury history (n = 191)	Healthy controls (n = 100)
Age (median, interquartile range)	48 (27–62)	35 (23–52)	29 (24–48)
Male sex	512 (61%)	104 (54.5%)	50 (50%)
Education level		*Not measured*	
• Low	158 (19%)		6 (6%)
• Middle	329 (40%)		29 (29%)
• High	342 (41%)		65 (65%)
Pre-injury physical disorders ‡	257 (31%)	71 (37.2%)	*Not measured*
Pre-injury psychiatric disorders	94 (11%)	10 (5.2%)	*Not measured*
Cause of injury			NA
• Motor vehicle accident	193 (23%)	5 (2.6%)	
• Fall	550 (66%)	92 (48.2%)	
• Violence	40 (5%)	7 (3.7%)	
• Other	53 (6%)	87 (45.5%)	
Loss of Consciousness	710 (85%)	*Not present by definition*	NA
Post-Traumatic Amnesia	682 (82%)	*Not present by definition*	NA
Hospital admission	509 (61%)	35 (18.3%)	NA

‡Includes cerebrovascular accident, heart diseases, hypertension, diabetes, asthma or other respiratory diseases, epilepsy, or any malignant disorder.
ⱢIncludes any psychiatric disorder necessitating treatment by a psychologist or psychiatrist or use of psychotropic medication, or both.
*All patients with mild TBIs that have either a pre-injury or a current rating at 2 weeks post injury
Abbreviations: mTBI = mild traumatic brain injury.

prevalence rates (median number of symptoms among patients with mTBI = 1, median number of symptoms among trauma patients without brain injury history = 0). Among the patients with mTBI, 22–32% fulfilled our criteria for ICD-10 PCS post injury, whereas only a minority of the trauma patients without brain injury history (6%) met the criteria (Table 2).

Ratings of symptoms in healthy controls

Commonly reported symptoms among healthy controls included sleep problems (31–36%), intolerance to alcohol or more anxious (27–29%), headache (23–26%), and fatigue (%). 21–29A total of 24–33% of the healthy controls screened positively for ICD-10 PCS (Table 2). This percentage was only 1%, however, after restricting the symptom ratings to 'often'. There were minor differences between their ratings from Time 1 to Time 2.

Pre-injury ratings of post-concussion-like symptoms

Patients with mTBI frequently endorsed pre-injury symptoms (median number of symptoms across all time points = 2). Approximately half of the patients (43–49%) reported experiencing three or more symptoms before their injury across all pre-injury ratings. Commonly reported pre-injury symptoms included fatigue and sleep problems (Table 2). Among the trauma patients without brain injury history, 28% reported three or more out of eight symptoms before their injury. Fatigue and sleep problems were also commonly reported in this group. Restricting to only those symptoms that were endorsed as 'often' resulted in substantially lower prevalence rates. A total of only 3–5% of the mTBI and non-brain-injured trauma control patients reported having experienced three or more symptoms before their injury.

Hypothesis 1: Both patients with mTBI and trauma patients without brain injury history will underestimate their pre-injury symptom level (i.e., 'good-old-days bias') by reporting fewer symptoms than healthy controls

Patients with mTBI reported more pre-injury symptoms and more often indicated having experienced three or more pre-injury symptoms compared to both trauma patients without brain injury history and healthy controls ($p < .001$). There were no statistically significant differences between trauma patients without brain injury history and healthy controls in the total number of ICD-10 symptoms ($p = .343$) or the number of patients experiencing three or more symptoms ($p = .322$).

Hypothesis 2: The consistency (i.e., test-retest reliability) of pre-injury ratings will be low in patients with mTBI

All four pre-injury ratings of post-concussion-like symptoms (2 weeks, 3 months, 6 months, and 12 months) differed significantly from each other (all $p < .001$; Table 3). As seen in Table 3, there were weak to moderate correlations between the total number of pre-injury symptoms across the four time points. A total of 444 patients completed all four pre-injury ratings. Among these patients, only half (n = 242, 55%) consistently reported three or more symptoms across all time points. The remaining 202 patients (45%) endorsed three or more pre-injury symptoms at some of the time points but not at other time points, and thus showed inconsistent pre-injury ratings. Inconsistency was not associated with demographic or pre-injury characteristics (Table 4).

Hypothesis 3: Patients with mTBI and post-injury PCS will be more likely to underestimate their pre-injury symptoms and be less accurate compared to patients with mTBI without post-injury PCS

Table 2. Overview of pre-injury and current post-concussion symptoms for mild TBI patients, trauma patients without brain injury, and healthy controls at different time points.

			Post-concussion symptoms according to the ICD-10								Total number of PCS symptoms	Meeting the ICD-10 criteria for PCS**
	Time period	N	Headache %	Fatigue %	Concentration problems %	Memory problems %	Dizziness %	Sleep problems %	Irritability %	Intolerance to alcohol or more anxious %	Median [IQR]	%
mTBI pre-injury symptoms	2 weeks	819	32% (4%)*	39% (9%)	35% (7%)	35% (4%)	21% (2%)	41% (12%)	35% (3%)	36% (8%)	2 [1-4]	49% (5%)
	3 months	789	32% (2%)	34% (6%)	30% (4%)	32% (4%)	21% (1%)	40% (9%)	27% (2%)	28% (7%)	2 [1-4]	43% (3%)
	6 months	638	34% (3%)	40% (8%)	35% (4%)	38% (3%)	23% (2%)	41% (10%)	32% (3%)	35% (8%)	2 [1-4]	49% (4%)
	12 months	593	33% (4%)	37% (6%)	30% (4%)	33% (3%)	24% (2%)	38% (8%)	31% (2%)	31% (8%)	2 [1-4]	45% (4%)
mTBI current symptoms	2 weeks	806	69% (27%)	79% (43%)	67% (25%)	61% (18%)	69% (23%)	57% (25%)	46% (12%)	47% (15%)	5 [3-7]	84% (32%)
	3 months	770	53% (16%)	66% (28%)	54% (19%)	56% (18%)	52% (11%)	55% (21%)	43% (11%)	43% (14%)	4 [2-6]	72% (22%)
	6 months	628	55% (15%)	68% (30%)	63% (20%)	63% (20%)	51% (11%)	61% (25%)	51% (13%)	49% (16%)	5 [3-7]	78% (25%)
	12 months	586	52% (13%)	66% (31%)	58% (20%)	63% (21%)	51% (12%)	59% (23%)	48% (13%)	48% (15%)	5 [3-7]	75% (24%)
Trauma patients without brain injury history symptoms ‡	Pre-injury	191	25% (5%)	29% (8%)	18% (4%)	13% (3%)	12% (1%)	34% (8%)	22% (3%)	20% (8%)	1 [0-3]	28% (3%)
	Current	191	28% (4%)	44% (16%)	26% (6%)	14% (4%)	19% (2%)	47% (16%)	28% (4%)	23% (9%)	2 [0-4]	38% (6%)
Healthy controls	Time 1	100	23% (4%)	21% (6%)	19% (5%)	16% (1%)	12% (0%)	31% (8%)	17% (1%)	29% (8%)	2 [1-2]	24% (1%)
	TIME 2	100	26% (4%)	29% (7%)	25% (4%)	20% (1%)	13% (0%)	36% (7%)	19% (2%)	27% (3%)	2 [1-3]	33% (1%)

*Number of patients who endorsed the symptom as 'sometimes' or 'often'; in parentheses are the number of patients who endorsed the symptom as 'often'.
**Number of patients who endorsed three out of eight post-concussion symptoms as 'sometimes' or 'often'.
‡ The questionnaire was completed by the trauma patients without brain injury history at approximately 3 weeks post-injury (IQR 1–7, range 0–51).
Note: a more red square means that a higher percentage of patients endorsed the symptom
Abbreviations. ICD-10 = International Classification of Diseases, 10th revision; PCS = post-concussion symptoms; IQR = interquartile range; mTBI = mild traumatic brain injury.

Table 3. A comparison of pre-injury ratings of patients with mTBI among the four different time points.

Rating	3 months	6 months	12 months
2 weeks	Similar rating: 75% PCS at 2 w, not at 3 m: 16% PCS at 3 m, not at 2 w: 9%p < .001 *r* = 0.66*	Similar rating: 74% PCS at 2 w, not at 6 m: 12% PCS at 6 m, not at 2 w: 14% *P* <.001 *r = 0.64*	Similar rating: 71% PCS at 2 w, not at 12 m: 15% PCS at 12 m, not at 2 w: 14% *P* < .001 *r = 0.49*
3 months	-	Similar rating: 75% PCS at 3 m, not at 6 m: 9% PCS at 6 m, not at 3 m: 16% *P* < .001 *r = 0.67*	Similar rating: 75% PCS at 3 m, not at 12 m: 11% PCS at 12 m, not at 3 m: 14% *P* < .001 *r = 0.54*
6 months		-	Similar rating: 77% PCS at 6 m, not at 12 m: 14% PCS at 12 m, not at 6 m: 9% *P* < .001 *r = 0.59*

*r = the Spearman correlation between the number of ICD-10 symptoms across different time periods.
Abbreviations: w = weeks; m = months.

Patients with PCS at six months reported substantially more pre-injury symptoms (median = 3, IQR = 2–5, mean = 3.3) compared to patients without PCS at six months (median = 1, IQR = 0–2, mean = 0.94, $p < .001$). Additionally, three or more pre-injury symptoms were also reported more often by patients with PCS at six months (62% vs. 3%, $p < .001$). Comparing patients with persistent PCS (PCS at both 2 weeks and 6 months), late-onset PCS (no PCS at 2 weeks, PCS at 6 months), resolved PCS (PCS at 2 weeks, no PCS at 6 months), and no PCS (no PCS at both 2 weeks and 6 months) also revealed statistically significant differences ($p < .001$). The percentage of patients that reported three or more pre-injury symptoms was highest among those with late onset PCS (65%) and those with persistent PCS (62%). Patients without PCS or those with resolved PCS both had very low percentages pre-injury symptoms (2% and 4%, respectively). In multivariable analyses, PCS at six months remained a strong predictor of reporting three or more pre-injury symptoms (Odds ratio (OR) = 43.2, 95% Confidence Interval (CI) 15.5–119.8). In addition, reporting three or more pre-injury symptoms was associated with older age (OR = 1.01, 95% CI 1.00–1.03) and pre-injury psychiatric disorders (OR = 4.05, 95%CI 1.89–8.67; Table 4).

Table 4. Exploratory analysis of factors associated with inconsistency of pre-injury ratings and reporting three or more pre-injury symptoms (measured at six months post injury) in patients with mild TBI.

	Inconsistency of pre-injury ratings	Three or more pre-injury symptoms
Variable	*OR (95% CI)*	*OR (95% CI)*
PCS diagnosis at 6 months		**43.2 (15.5–119.8)**
Female sex	1.15 (0.78–1.70)	1.37 (0.92–2.05)
Age (per year)	1.01 (0.99–1.02)	**1.01 (1.00–1.03)**
Education		
• Low	*Reference*	*Reference*
• Middle	0.84 (0.48–1.45)	1.23 (0.70–2.17)
• high	0.80 (0.46–1.39)	1.23 (0.70–2.17)
Pre-injury physical disorders‡	1.12 (0.70–1.80)	0.93 (0.60–1.60)
Pre-injury psychiatric disorders	0.68 (0.35–1.32)	**4.05 (1.89–8.67)**

‡Includes cerebrovascular accident, heart diseases, hypertension, diabetes, asthma or other respiratory diseases, epilepsy, or any malignant disorder.

ȽIncludes any psychiatric disorder necessitating treatment by a psychologist or psychiatrist, use of psychotropic medication, or both.

Note: OR, 95% CIs that do not cross 1 are bolded.

Abbreviations. OR = Odds ratio; 95% CI = 95% Confidence interval; PCS = post-concussion syndrome.

We also assessed whether PCS at six months was associated with inconsistency. Patients with PCS at six months were more often inconsistent in their pre-injury assessment than patients without PCS (50% vs. 31%, $p = .001$). The association between PCS at six months and inconsistency remained statistically significant after correcting for sex, age, education, and pre-injury physical and psychiatric complaints (OR = 2.33, 95% CI 1.40–3.87). Comparing the four different groups revealed that patients with late-onset PCS were most often inconsistent (69%), followed by patients with persistent PCS (48%) and resolved PCS (45%). Patients without post-injury PCS had the lowest inconsistency (10%, $p < .001$).

Discussion

Post-concussion symptoms, and PCS, are usually conceptualized by the patient or health care provider by comparing current symptoms with how the person felt and functioned prior to the injury. This is done by having the person think back, and retrospectively conceptualize or rate, pre-injury symptoms. During this study, we investigated the reliability and validity of such retrospective ratings of pre-injury symptoms among a representative sample of patients with mTBI in the Netherlands, and we compared their ratings to those of trauma patients without brain injury history and healthy controls. The accuracy of pre-injury ratings is critically important, because some self-report instruments (e.g., the RPQ (19) and the HISC (18)) require patients to compare their current symptom level with their symptom level pre injury. When patients do not remember their pre-injury status accurately or demonstrate cognitive bias (e.g., the good-old-days bias), this may increase the possibility of an incorrect PCS diagnosis after injury. Interestingly, we did not find evidence for the good-old-days bias in our sample. In fact, we found almost the opposite – those people who endorsed the greatest number of symptoms at six months following their injury were also most likely to endorse greater symptoms before their injury. We found that approximately half of the patients with mTBI were inconsistent in their retrospective assessment of symptoms over different time periods following injury, and a post-injury diagnosis of PCS was strongly associated with inconsistency in retrospective ratings of pre-injury symptoms.

In this study, we included post-concussion symptoms and post-concussion-like symptoms endorsed as 'sometimes' or 'often', resulting in a very high prevalence in reporting a constellation of symptoms among all groups, both before and after injury. Nevertheless, prevalence rates were on the high end of the spectrum, particularly for studies in which compensation is not involved. However, they were in line with previous studies performed in patients with mTBI using the RPQ with the cutoff of 'mild or worse' (4,6,33,34). It is open to question whether all patients identified or 'diagnosed' with PCS in these studies truly reflect a subgroup with clinically significant symptomatology. Possibilities to reduce the potential high rate of false-positives include the calculation of difference scores between pre- and post-injury assessment, which was performed in a previous investigation using the UPFRONT data (30). Another possibility might be to restrict analyses to symptoms endorsed as 'often' on the HISC or 'moderate or worse' on the RPQ. In this study, we found preliminary evidence that this cutoff may better discriminate between patients with mTBI and both control groups, and also between the pre- and post-injury assessments of patients with mTBI. The fact that the HISC was used in this study instead of the RPQ, which is the most applied questionnaire for both research and clinical purposes, should not be seen as a limitation, because we focused on certain symptoms that fit the diagnosis of PCS and did not look at the total number of symptoms, for which the RPQ is normally used (19).

Based on previous research, we hypothesized that both patients with mTBI and trauma patients without brain injury history would report fewer pre-injury symptoms than healthy controls, congruent with the 'good-old-days' bias theory. In contrast, however, we found that patients with mTBI reported significantly more pre-injury symptoms than both control groups, whereas the trauma patients without brain injury history did not differ significantly from the healthy controls. Thus, we did not find evidence of the good-old-days bias in this large cohort of patients with mTBI. There might be several reasons for this. The patients with mTBI in the UPFRONT study were older in comparison to both control groups and one-third of the sample reported pre-existing physical comorbidities. Because post-concussion-like symptoms are nonspecific, the endorsement of a large number of pre-injury symptoms in our sample might be the direct consequence of physical comorbidities, other age-related symptoms, or life stressors that were experienced pre injury. Notwithstanding, the age of the patients with mTBI in our sample (median age = 48 years) was comparable to the age of the patients with mTBI included in the study by Iverson et al (21). (mean age = 41.5 years). Iverson and colleagues (21) report, however, that only 20% of the patients with mTBI endorsed three or more pre-injury symptoms as 'mild or worse', while we found a percentage of 43–49%. A major difference between the two cohorts is that we included a sample of patients with mTBI who presented to the emergency department of level I trauma centers, whereas Iverson et al (21). included injured workers who received compensation benefits. Such a population might be more vulnerable to a true good-old-days bias (20) or might distort or misrepresent their pre-injury symptoms and functioning in relation to their compensation claim.

Another reason for the significant difference between the pre-injury ratings of the patients with mTBI and the healthy controls is that the healthy controls in this study might not be representative of the general population. They are relatively young and highly educated, and therefore, they may have endorsed fewer symptoms. Previous research in healthy adults or trauma patients without brain injury history showed higher rates of post-concussion symptoms (10,21), comparable to those found in our sample of patients with mTBI.

Similar to the study by Silverberg et al (20)., we found that patients with post-injury PCS reported substantially more pre-injury symptoms compared to those without post-injury PCS. Pre-injury symptom ratings among patients with PCS were also substantially higher than reported in the general population (21). The endorsement of pre-injury symptoms was also associated with older age and pre-injury psychiatric disorders. Because post-concussion-like symptoms are nonspecific (10), it is likely that preexisting mental health problems or age-related complaints have influenced both the pre-injury and current symptom ratings in this group.

In this study, we also assessed the consistency of pre-injury ratings over time. In concordance with our hypothesis, we found that approximately half of the patients with mTBI inconsistently reported their pre-injury symptom level during the first year following injury. Our results are in line with the study by Yang et al (24). who studied pre-injury ratings at both one and three months post injury. They found a trend toward an increase in pre-injury symptoms reported at three months compared to one-month following injury. Inconsistency of pre-injury ratings might be influenced by the fact that memories have to be reconstructed and might be influenced by subjective beliefs and perception. Some people may have simply forgotten whether they experienced certain symptoms in the past or they may have reframed them (35). Inconsistency was especially apparent for patients with post-injury PCS; even those with resolved PCS (i.e., PCS at 2 weeks but not at 6 months) had a higher rate of inconsistency than those who never fulfilled the criteria for PCS post injury. It is possible that patients with post-injury PCS are dealing with recall bias, which means that they have difficulties remembering when the symptoms first occurred (i.e., did the symptoms start pre injury or post injury?). In addition, some of the post-concussion symptoms themselves (e.g., fatigue, concentration problems, memory problems) may directly influence the ability to accurately complete a self-report questionnaire and thereby may have influenced the consistency of the pre-injury assessment. It is possible that some people in this study who reported the greatest symptoms at six months following injury are more likely to conceptualize those symptoms as longstanding and due to factors separate from their mTBI.

Strengths of our study include the large number of patients with mTBI and the representativeness of the study sample. In addition, pre-injury symptoms were assessed at four different time points and ratings were compared to both trauma patients without brain injury history and healthy controls. Therefore, the current study represents the most up to date and comprehensive study in assessing the reliability of pre-injury symptom reporting among patients with mTBI. The main limitation of our study was that the healthy control group was not comparable to both patient groups. Therefore, the relatively low number of symptoms reported might be the direct consequence of the younger age and the higher education level in this group. Healthy controls were recruited via the personal and occupational network of the investigators of the UPFRONT study, which could have introduced bias. An alternative approach might be to include 'friend controls', a method that is currently used by the TRACK-TBI study (36). A second limitation concerns the number of patients that were lost to follow-up during the 12-month period. A total of 806 patients completed the two-week assessment, whereas 586 were still involved at 12 months. All pre-injury ratings were completed by 444 patients. Although attrition is common in mTBI studies (4,6,37), it might have resulted in selection bias that could have influenced our study results; i.e. if patients with post-injury PCS are more likely to participate in the follow-up assessment and these patients are less consistent in their pre-injury assessment, it is possible that the large percentage of inconsistent ratings in our study is in fact an overestimation. Additionally, the confidence interval for PCS diagnosis at six months as a predictor of three or more pre-injury symptoms was wide. Lastly, the RPQ is the most often used questionnaire to assess PCS and is recommended in the common data elements (38). However, in this study we used the HISC, which could make the results of this study more difficult to compare with previous literature although it was possible to delineate patients with PCS based on the available symptoms.

Our study reveals the difficulty in accurately obtaining pre-injury ratings of symptoms among patients with mTBI. More than half of the patients inconsistently reported their pre-injury functioning over time. Patients with post-injury PCS had strikingly high ratings of pre-injury symptoms and were also more likely to report symptoms inconsistently over time. This has implications for the accuracy of self-report measurements designed to assess post-concussion symptoms and PCS in patients with mTBI. When patients are not able to accurately recall their pre-injury status, the validity of their perceived post-injury status could also be doubted. Another problem is that the overlap with psychiatric disorders is not captured in a self-report questionnaire. Patients with pre-injury PCS more often had psychiatric premorbidity and this premorbidity also showed a strong association with post-injury PCS. Therefore, some of the post-injury PCS diagnoses might actually be the consequence of preexisting psychiatric problems rather than the sustained mTBI. For clinical purposes, we recommend assessing post-concussion symptoms in a more comprehensive way by using a semi-structured or structured interview. In such an interview, a clinician may investigate the frequency and severity of symptoms and whether these symptoms influence functioning and quality of life. A clinician may also examine when the symptom first occurred and whether there is overlap with psychological factors such as emotional distress. For research purposes, however, such an approach might not be feasible.

Declaration of interest

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