ORIGINAL ARTICLE

Characteristics of a Mild Head Injury Subgroup With Extreme, Persisting Distress on the Rivermead Postconcussion Symptoms Questionnaire

Ned L. Kirsch, PhD, Marita B. de Leon, PhD, Ronald F. Maio, DO, Scott R. Millis, PhD, Cheribeth U. Tan-Schriner, PhD, Shirley Frederiksen, RN, MS

ABSTRACT. Kirsch NL, de Leon MB, Maio RF, Millis SR, Tan-Schriner CU, Frederiksen S. Characteristics of a mild head injury subgroup with extreme, persisting distress on the Rivermead Postconcussion Symptoms Questionnaire. Arch Phys Med Rehabil 2010;91:35-42.

Objective: To examine baseline variables and identify characteristics of participants with extremely high reports of symptoms (ie, outliers) 12 months after mild head injury (MHI).

Design: A prospective cohort study of MHI with and without loss of consciousness (LOC) and/or posttraumatic amnesia (PTA) recruited from and interviewed at the emergency department (ED), with a follow-up telephone interview at 12 months.

Setting: Level II community hospital ED.

Participants: Participants (n=58) with MHI and LOC less than or equal to 30 minutes and/or PTA less than 24 hours and participants (n=173) with MHI but no PTA/LOC. Inclusion criteria: age greater than or equal to 18 years, less than or equal to 24 hours after injury, Glasgow Coma Scale score greater than or equal to 13, and discharge from the ED. Fourteen (6%) participants had extremely high scores on the Rivermead Postconcussion Symptoms Questionnaire (RPQ).

Main Outcome Measures: RPQ and questions on health services use and litigation.

Results: Characterizing the outlier cases are prior head injury, preinjury disability, history of substance use, unemployment, and elevated somatic symptoms at the ED. At 12 months, outliers had higher use of health services and litigation.

Conclusions: The existence of a subgroup with a distinctive pattern of baseline characteristics in combination with elevated somatic symptoms at the time of presentation to the ED suggests that further taxonomic distinctions may be warranted for the MHI population, each requiring appropriately targeted interventions for addressing symptomatic complaints.

Key Words: Brain injuries; Rehabilitation.

ESTIMATES OF THE RATE of persisting symptoms after MHI range from 6%[1] to 24% to 40%.[2-4] These include (1) alterations in cognitive ability[5-7]; (2) changes in mood, personality, and behavior[6,8-10]; (3) limitations of everyday functioning,[11] such as disrupted work status[3,6,12,13]; and (4) limited participation in social activities.[9,14-16]

The persistence of these symptoms after MHI has remained a perplexing phenomenon,[17,18] because recovery patterns often appear inconsistent with the degree of known neurologic impairment or accident characteristics. For example, several studies have demonstrated a dose effect for MHI, such that increasing injury severity is associated with increasing symptom severity.[19-21] However, others have been unable to demonstrate such an effect,[5,22,23] or counterintuitively, report that patients having milder head injury also have worse outcomes.[22,24-30]

As a result of these observations, it has become increasingly important to examine the clinical characteristics of various MHI subgroups, including those with and without neurologic changes. The purpose of this study is to examine preinjury (ie, baseline) and injury characteristics of a subgroup of outliers with highly elevated postconcussion complaints 1 year after MHI and to determine which of these characteristics differentiate the outlier subgroup from other MHI patients. In order to place this subgroup into perspective, we first briefly describe other proposed taxonomic subclassifications of the MHI population for whom persisting symptomatic complaints have been attributed to various causes. Factors associated with persisting symptoms after MHI include identifiable neuropathology, psychologic response to the injury or traumatic event, motivation, and specifically pertinent to this study, baseline characteristics.

Neurologic changes after MHI, in particular white fiber changes that are detectable with diffusion tensor imaging,[31,32] and their resolution over time have been reported.[33,34] However, to the limits of our review, and as recently noted,[35,36] no prospective studies have as yet been published that demonstrate

List of Abbreviations

ED	emergency department
GLM	General Linear Model
LOC	loss of consciousness
MHI	mild head injury
MTBI	mild traumatic brain injury
PTA	posttraumatic amnesia
RPQ	Rivermead Postconcussion Symptoms Questionnaire

From the Departments of Physical Medicine and Rehabilitation (Kirsch, de Leon), Emergency Medicine and the Injury Research Center (Maio), and Emergency Medicine (Frederiksen), University of Michigan, Ann Arbor, MI; Department of Physical Medicine and Rehabilitation, Wayne State University, Detroit, MI (Millis); and the Michigan Public Health Institute, Okemos, MI (Tan-Schriner).

Supported by the Centers for Disease Control (grant no. R49/CCR523223-01), the National Institutes of Health, the National Institute of Child Health and Human Development, and the National Center for Medical Rehabilitation Research (grant no. 5-T32-HD007422-17).

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

Correspondence to Ned L. Kirsch, PhD, Dept of Physical Medicine and Rehabilitation, University of Michigan Health Systems, 355 Briarwood Circle, Ann Arbor, MI 48109-5742, e-mail: *nlkirsch@umich.edu.* Reprints are not available from the author.

0003-9993/10/9101-00370$36.00/0
doi:10.1016/j.apmr.2009.09.019

an association between changing symptom patterns and white fiber status.

Alternative nonphysiologic explanations for persisting symptoms have also been proposed. Depression,[19,37,38] posttraumatic stress disorder,[19,39] limited social support,[39] difficulties with social integration,[15] expectations of poor outcomes,[40-42] and misattribution of preinjury symptoms to a recent trauma[43-45] all may individually contribute to protracted recovery. Decreased motivation associated with injury-related compensation has also often been identified as predictive of delayed recovery.[9,17,46-48] Conversely, the role of motivation can be inferred from studies of sports-related MHI. In this cohort, the estimated recovery period is shorter, with symptoms returning to baseline within 7 to 14 days,[49-51] in contrast with non–sports-related MHI, with estimated recovery often extending over 3 to 12 months.[1,4,17,52,53]

Last, baseline functioning has been reported to be related to poor outcomes after MHI. Preinjury physical health,[54,55] psychologic health,[27,56,57] and social functioning[14,56] have been identified as predictors of persisting symptoms more so than, or instead of, head injury characteristics.

In our earlier work, we reported the predictive value of preinjury health status for persisting fatigue[30] and postconcussion symptoms.[54] We specifically found that a subgroup of patients with MHI without PTA or LOC had worse outcomes than a group with nonhead injuries and a group having sustained more severe MHI—that is, with PTA or LOC. This paradoxical finding, similar to those of several studies cited,[22,24-30] led us to explore possible differences between these MHI subgroups.

It should be noted that we use the term MHI rather than MTBI based on the distinction proposed by Kay et al.[58] Additionally, we follow the recommendation of McLean and Clauw[59] to use neutral and descriptive rather than definitive classification terms because of the uncertainty of pathogenesis of symptoms after head injuries. In this study, we use the descriptive terms "with or without PTA or LOC" to describe the 2 MHI groups. These descriptive terms are part of the criteria in the case definition of MTBI as proposed by the American Congress of Rehabilitation Medicine.[60]

In contrast with our earlier work, which reported outcomes for our entire MHI sample,[30,54] for this report, we focus analyses on a subsample of outlier participants (extracted from our larger, previously reported sample) who had extremely high scores on the RPQ 12 months after injury. We hypothesize that these outlier cases represent a coherent subgroup of persons with MHI. We specifically examine baseline (ie, preinjury and injury) variables to identify distinctive characteristics of this outlier group.

METHODS

Data for this study were derived from a larger data set that prospectively investigated postconcussion symptoms and other outcomes.[30,54] The study protocol was approved by the institutional review boards of the University of Michigan Medical School, Saint Joseph Mercy Health System, and the Michigan Public Health Institute.

Participants

Procedures regarding recruitment and data collection are comprehensively presented in our earlier work.[30,54] To summarize, participants comprised an inception cohort of patients with minor head and nonhead injury evaluated and discharged directly from the ED. Inclusion criteria were age greater than or equal to 18 years, Glasgow Coma Scale score greater than or equal to 13, not meeting the institution's criteria for activation of the adult trauma team, presentation to the ED within 24 hours of injury, and direct discharge from the ED. Exclusion criteria were transfer from another hospital and inability to speak English. Participants were classified as having had a head injury based on evidence in the medical record and patient responses to multiple questions regarding indicators of an injury to the head, altered consciousness, or accident characteristics that indicate a blow to the head. All discrepancies were resolved by attending medical staff. LOC and PTA were likewise determined through the medical record and self-report, and patients were excluded if any of the following were true: LOC greater than 30 minutes, LOC not attributable to head trauma, PTA greater than 24 hours, or patient still in state of PTA at the time of interview (Galveston Orientation and Amnesia Test score <76). When PTA length could not be determined, it was estimated to be less than 24 hours if the patient was interviewed and clear of PTA within 24 hours of the presenting injury. The rigorous procedures of determining group membership are illustrated in a previous article (fig 1).[30] From the larger cohort, we derived 2 MHI subgroups: a group with LOC less than or equal to 30 minutes and/or PTA less than or equal to 24 hours (head injury with PTA and/or LOC) and a group without any PTA or LOC (head injury only).

The sample size at the ED was 339 participants with MHI (head injury with PTA and/or LOC, n=94; head injury only, n=245). Retention rates at 12 months postinjury were 62% for the head injury with PTA and/or LOC group (n=58) and 71% for the head injury only group (n=173).

Identification of outliers. From this data set, an outlier subsample was extracted. A conservative criterion of 2.0 SDs above the RPQ study sample mean at 12 months (mean ± SD, 12.0±15.2; cut-off RPQ score=42) was established for determining outlier status. Fourteen outlier cases were thus identified from the total sample of 231 (6%), with 13 (8%) of 173 participants with head injury only and 1 (2%) of 58 participants with head injury with PTA and/or LOC.

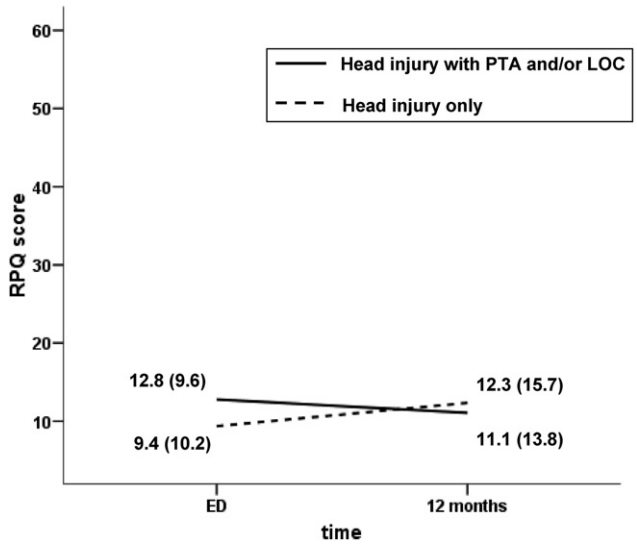

Fig 1. RPQ mean scores (SD) at ED and 12 months of the head injury with PTA and/or LOC (n=58), and head injury only groups (n=173).

Measures

Demographics and injury characteristics. Demographic variables were obtained from a structured patient interview, adapted from the Colorado Traumatic Brain Injury Registry and Follow-up System[61] and verified against the medical record where possible. These included age, sex, education, marital status, and employment status. Information related to the MHI was obtained from the medical record and included cause of injury and any computerized tomography findings. LOC was also assessed through the patient structured interview. PTA was assessed with the Galveston Orientation and Amnesia Test. All medical variables were verified by attending staff, if necessary.

Baseline functioning. Measures of baseline status, also obtained from the structured interview, included dichotomous questions about medical history, mental health issues needing counseling, drug/alcohol problems needing treatment, prior head injuries (characterized by being "dazed or disoriented" or having lost consciousness), having a prior disability, involuntary unemployment because of termination (independent of disability status), and prior need for assistance. Need for assistance was assessed with dichotomous items about whether the participant had received any help one month prior to injury in various areas that are additionally indicative of 3 of the conditions mentioned (disability, mental health, substance use). These items were chosen as indicators of baseline functioning specifically because their dichotomous format appeared to be less subject to potential stress-induced response bias, given the participant's circumstance at the time of study interview (ie, being concurrently examined in an ED).

Outcome measures. Severity of symptomatic complaints at 12 months postinjury was determined with the RPQ.[62] Also included were additional questions regarding health-related services received "due to [the] injury" in the previous 9 months (ie, from the third month to twelfth month after injury) through various service settings such as EDs, hospital departments or clinics, physicians, or other rehabilitation and mental health care providers. Finally, litigation status was included in the analyses as another possible characteristic of the outlier group, broadly determined as positive if any of the following were true: the participant was actively involved in litigation, had received services from a lawyer or a paralegal, had consulted with an attorney, or was considering consulting an attorney regarding the injury.

Procedure

Recruitment and consent procedures were completed in the ED. Participants were interviewed for baseline information between other examinations and treatments. Follow-up telephone interviews were conducted at 1, 3, and 12 months. For this study, only the baseline and 12-month follow-up data are reported. At each of the follow-up time points, a maximum of 10 attempts was made to contact each participant. They were given $25 after completion of the ED interview and $75 at 12 months to maximize retention rates.

Data Analysis

Statistical analyses were performed with SPSS version 17.[a] Two-tailed tests of significance with alpha level of .05 were used.

Differences between outliers' and nonoutliers' baseline characteristics and service use were assessed with Pearson chi-square tests of independence with Yates correction, because of the small sample size of the outlier group, and with *t* tests for continuous variables. GLM repeated-measures analysis was done to assess differences in RPQ scores of the head injury only and head injury with PTA and/or LOC groups at the ED and at 12 months, and also to determine significance of changes in scores over time for each of the groups. This analysis was done first with the entire MHI sample, and then with outliers removed to determine whether the outlier sample was accounting for our earlier reported paradoxical finding of worse outcomes for the head injury only group.

RESULTS

Baseline Characteristics

Analyses were based on 14 identified outlier cases. Visual inspection of the data revealed a pattern of distinctive preinjury characteristics. To identify which of these characteristics significantly differentiated between the groups, we compared endorsement percentages for the outlier and nonoutlier groups (table 1). The groups differed significantly for several characteristics, with outliers more frequently reporting preinjury disability, history of services for drug/alcohol use, unemployment because of job termination, and prior head injury. We additionally examined the outliers' reports of symptoms at time of ED presentation. More of these cases also had outlier RPQ

Table 1: Baseline Characteristics of the Outlier and Nonoutlier Groups

Baseline Characteristics	Outliers (n=14)	Nonoutliers (n=217)	Total (N=231)	*P**	φ Coefficient
With a disability	8 (57)	31 (14)	39 (17)	.000	.27
Prior mental health counseling	9 (64)	79 (36)	88 (38)	.072[†]	.14
History of drug/alcohol services	7 (50)	36 (17)	43 (19)	.006	.21
Unemployment because of job termination	4 (29)	5 (2)	9 (4)	.000	.32
Prior head injury with LOC or was "dazed or disoriented"	9 (64)	39 (18)	48 (21)	.000	.27
Female	9 (64)	125 (58)	134 (58)	.832	.03
Married	8 (57)	90 (42)	98 (42)	.384	.08
High school or less education	7 (50)	66 (31)	73[‡] (32)	.223	.10
With PTA or LOC	1 (7)	57 (26)	58 (25)	.200	.11
Motor vehicle collision	3 (21)	77 (36)	80 (35)	.435	.07
RPQ outlier score at ED[§]	6 (43)	5 (2)	11 (5)	.000	.45

NOTE. Values are n (%) unless otherwise indicated.
*Yates correction.
[†]Fisher exact test, $P=.045$; other variables with similar *P* using Fisher exact test.
[‡]One case with missing data.
[§]RPQ score >2 SD above study group mean (mean ± SD, 10.2±10.1; cut-off score=30).

scores at the time of injury (6 of 14) than those who were not outliers at 12 months (5 of 217). The 2 groups did not significantly differ in regard to sex, marital status, education, motor vehicle collision as cause of injury, having PTA or LOC (see table 1), and age (mean age ± SD for the outlier and nonoutlier groups were, respectively, 41.4±13.4 and 41.2±18.8; t=.04; P=.968).

Outcomes at 12 Months After Injury

Change in Rivermead Postconcussion Symptoms Questionnaire scores. The outlier group had, by definition, extremely high scores on the RPQ at 12 months. We therefore explored the possibility that outliers account for previously reported paradoxically worse outcomes for participants with MHI without LOC or PTA.[30]

We first compared RPQ scores that had been obtained at the ED and at 12 months from our entire sample (ie, with outliers included), comparing the head injury only group and head injury with PTA and/or LOC group. We then repeated this analysis with all outliers removed from either group. The GLM repeated-measures analysis for the entire sample (see fig 1) revealed a significant interaction effect of time by group ($F_{1,229}$=5.71; P=.018; partial η^2=.02) and a significant increase in RPQ scores over time for the head injury only group (P=.003; partial η^2=.04). However, with the outliers removed (fig 2), there were no significant changes in RPQ scores over time for either injury group, while RPQ scores for the extracted outliers increased dramatically ($F_{1,228}$=62.72; P=.000; partial η^2=.22).

We understand that there is questionable applicability of GLM repeated-measures analysis to this comparison because of the small sample size, different distribution, and variability of the outlier group. However, the notably distinct RPQ score patterns over time for the outlier and nonoutlier groups are compelling. Specifically, RPQ scores for the MHI subgroups without the outliers were stable, while the RPQ scores at 12 months for the outliers reflected a substantial worsening of reported symptoms.

Use of health and litigation services. At 12 months, participants were asked how many times they had received various health care services "due to [the] injury" over the prior 9 months (ie, from the time of the last study interview at 3 months). Table 2 compares the percentages of outlier and nonoutlier participants according to total number of health care visits. Of the outlier group, 79% reported at least 3 visits, while 77% of the nonoutlier group reported no visits of any kind (χ^2=32.34; P=.000; φ coefficient=.398). Additionally, at 12 months, 43% of the outliers were in some stage of the litigation process, compared with only 13% of the nonoutlier group (χ^2=6.75; P=.009; φ coefficient=.196).

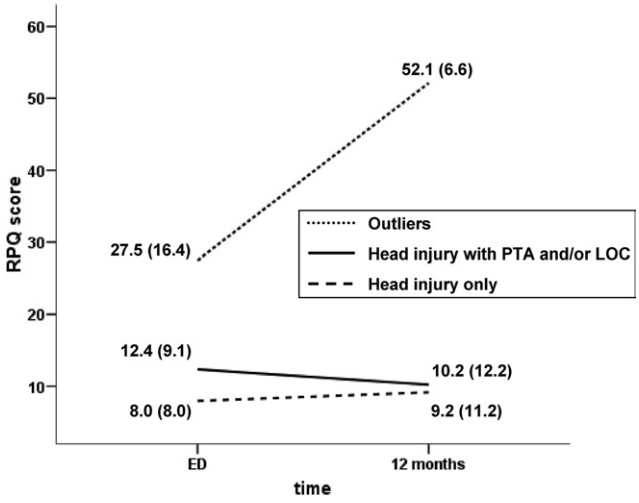

Fig 2. RPQ mean scores (SD) at ED and 12 months of the head injury with PTA and/or LOC (n=57), head injury only (n=160), and outlier groups (n=14).

Table 2: Percentages of Outliers and Nonoutliers by Number of Health-Related Visits

Number of Health-Related Visits	Outliers (n=14)	Nonoutliers (n=217)	Total (N=231)
0	2 (14)	167 (77)	169 (73)
1	1 (7)	8 (4)	9 (4)
2	0 (0)	11 (5)	11 (5)
3 or more	11 (79)	31 (14)	42 (18)

NOTE. Value are n (%). Yates correction and Fisher exact test P=.000, φ coefficient=.40. For statistical analysis, categories were collapsed into 2 categories of "3 or more" and "2 or less" to adjust for cells that did not meet minimum cell size requirements.

Predicting Outlier Status at the Time of Emergency Department Presentation: A Post Hoc Analysis

As additional analyses, we explored the data presented in table 1 to determine which preinjury characteristics and symptomatic concerns (as measured by the RPQ in the ED) would optimally classify participants into outlier and nonoutlier groups. Prior head injury, disability, and unemployment had comparable effect sizes in distinguishing between these 2 groups.

However, prior head injury identified the largest percentage of outlier cases (9 of 14) relative to any of the other baseline characteristic. Prior head injury was still not an acceptable sole classification criterion because it resulted in 18% (39) being falsely classified as at risk for outlier status.

When all 4 preinjury characteristics are considered, a criterion of any 2 out of the 4 distinctive characteristics correctly classified 10 (71%) of 14 of the outliers and incorrectly classified 20 (9%) 217 of the nonoutliers (table 3). The absolute number of false positives based on this criterion may also be considered unacceptably high in many clinical settings, because the health care costs associated with provision of services to so many false-positive cases may be prohibitive. We therefore additionally explored whether any other baseline variables would maximize the percentage of correct identification to the 2 groups. However, no significant differences were found for any demographics or injury characteristics (having had PTA/LOC and motor vehicle accident as cause of injury).

Because total-score RPQ outlier status at the ED only correctly classified 43% (6 of 14) of the outliers, as final exploratory analyses, we examined the possibility that a specific pattern of elevated symptoms, as reported on the RPQ, might yield better predictions of group membership. Specifically, we examined scores for 3 RPQ subscales (somatic, cognitive, affective) adopting the method used by Smith-Seemiller et al.[63] The outlier group had significantly higher scores only on the somatic subscale (mean score ± SD for the outlier and nonoutlier groups were, respectively, 17.0±9.0 and 8.5±6.4; t=3.00; P=.006). Examination of each of the 9 RPQ somatic symptoms revealed that more outliers than nonoutliers reported

Table 3: Percentages of Outliers and Nonoutliers Positive for Baseline Characteristics and RPQ Symptoms

Criteria at ED	Total Sample		
	Outliers (n=14)	Nonoutliers (n=217)	Total (N=231)
Baseline characteristics			
With prior head injury	9 (64)	39 (18)	48 (21)
With prior head injury and 1 other baseline characteristic	8 (57)	16 (7)	24 (10)
With 2 or more baseline characteristics*	10 (71)	20 (9)	30 (13)
RPQ symptoms			
RPQ outlier at the ED†	6 (43)	5 (2)	11 (5)
At least 1 somatic symptom‡	13 (93)	88 (41)	101 (44)
Baseline characteristics and somatic symptoms			
With 2+ baseline characteristics and at least 1 somatic symptom	10 (71)	8 (4)	18 (8)
With prior head injury and at least 1 somatic symptom	9 (64%)	16 (7)	25 (11)

NOTE. Values are n (%). All differences are significant at $P=.000$.
*Any 2 of 4 baseline characteristics: prior head injury, disability, unemployment, services for drug/alcohol use.
†RPQ score >2 SD above study group mean (mean ± SD, 10.2±10.1; cut-off score=30).
‡Somatic symptoms include headache, blurred vision, and light sensitivity.

the following symptoms as moderate or severe: headache (90% vs 37%; $P=.019$), blurred vision (50% vs 0%; $P=.004$), and light sensitivity (70% vs 15%; $P=.009$). Using the criterion of having at least 1 of these 3 somatic symptoms in the ED, in combination with having 2 or more baseline characteristics, substantially reduced the percentage of nonoutliers incorrectly classified as outliers, without reducing the number of those correctly classified as true outliers.

Table 3 summarizes percentages of true positives (correct identification of outliers) and false positives (incorrect classification of nonoutliers) applying all of these exploratory combinations of variables to the entire sample. All combinations are presented in the table because their application in regard to case management and clinical decision-making may be critically dependent on clinical setting, purpose of evaluation, and availability of resources.

DISCUSSION

We extracted and analyzed outlier cases with extremely high RPQ scores at 12 months after an MHI that had initially been evaluated in an ED. The outlier group is distinctively different from the rest of the sample in baseline characteristics (including prior head injury, disability, history of substance use, unemployment) and elevated somatic symptoms at the ED. Having brief PTA or LOC as an injury characteristic did not significantly distinguish between the outlier and nonoutlier groups. This finding is consistent with our earlier reports that preinjury physical and mental health status, rather than head injury severity, are predictive of postconcussion syndrome[54] and fatigue[30] at 12 months.

Poor outcomes are evident for the present outlier subsample. There are significantly higher rates of health care service use and pursuit of litigation over the first year postinjury compared with our substantially larger nonoutlier group. Additionally, the high symptom reporting at the ED not only remained unresolved but also actually worsened significantly over time, contrary to typical symptom resolution patterns reported in other studies of MHI[1,49,64] or for our nonoutlier group.

We further present exploratory findings suggesting that extreme symptom reporting at 12 months may be determined at the time of injury, to varying degrees, by different combinations of variables. Of the preinjury variables that significantly differentiated the outlier and nonoutlier groups, prior head injury is the most predominant characteristic of the outlier group. The effect of multiple head injuries is an important factor in determining risk of persisting problems, as has been described in previous studies.[55,64] However, prior head injury is not a sufficient condition alone in risk assessment for outlier status, because 39 of 45 participants with prior head injury did not convert to outlier status and reported good recovery at 12 months. Assessment of risk for future problems is enhanced by examining multiple factors. The combination of having 2 or more baseline characteristics (prior disability, history of services for drug/alcohol use, prior head injury, unemployment) and moderate to severe somatic symptoms (headache, light sensitivity, blurred vision) characterize those who would be extremely symptomatic at 12 months and eliminates most of those who are not symptomatic. However, because of the exploratory and post hoc nature of these analyses, this finding warrants further prospective verification. Studies on identification and further refinement of prediction algorithms would enable clinicians to accurately assess, at the time of injury, relative risk for developing persisting problems, independent of the recent MHI reported in the ED.

Study Limitations

In regard to study limitations, the results and their implications are restricted to those MHI cases with the very mildest of injuries. The sample characteristics of such mild injuries were no LOC or PTA (our head injury only group), or at most very brief LOC or PTA (our head injury with PTA and/or LOC group) and direct discharge from the ED. Additionally, computerized tomography scans were most often not prescribed, or if prescribed (38% of our sample) revealed no accident-related neurologic changes. In the absence of comprehensive and sensitive neuroimaging data, we cannot be certain of our participants' neurologic status.

Another limitation is that we did not specifically inquire about preinjury health care use. Although we know that outliers' symptomatic complaints after injury increase significantly over time, we are uncertain whether their associated reports of greater health care visits (compared with nonoutliers) represent a change subsequent to injury or a continuation of a preinjury health care use pattern. It is possible that for some persons, both their reported concerns after MHI and the health care sought for those concerns may be misattributed to the injury, even if use rates do not change. Clearly, this can only be clarified with subsequent prospective studies.

These findings raise several important issues. In regard to the characterization of MHI samples, in general, the data indicate that the effect of an outlier group can be so extreme that erroneous conclusions may be reached about MHI population mean symptom characteristics. One such erroneous conclusion may be that there are paradoxical differences between patients who do and do not sustain brief loss of consciousness (ie, that less severely injured patients report greater impairment). Our data suggest that this is only the case if outliers are not accounted for.

Another potentially erroneous conclusion would be that symptomatic complaints for persons with MHI either do not resolve over time or intensify. Our findings indicate that this is not characteristic of the general MHI population but does occur for a very small outlier group potentially identifiable at the time of injury.

More generally, our data support the impression that the MHI population is, as a whole, comprised of several subgroups, each having distinct clinical presentations at the time of initial evaluation and distinct patterns of symptom evolution over time. This, in turn, suggests that when patients present to the ED, it is critical to identify the subgroup to which they can be predominantly assigned and that evaluation and disposition protocols be implemented that specifically address the characteristics of those group members.

For all of those who at the time of ED evaluation do not have the characteristics of the outlier subgroup, prophylactic discharge and disposition protocols do appear worth consideration.[65,66] In contrast, for those patients who, at the time of ED presentation, have characteristics of the outlier group, careful monitoring of nonresolving or increasing symptomatic complaints is warranted during the first year after injury, particularly because, based on our data, members of the outlier group appear to use relatively expensive health care resources that may not be directly pertinent. For these persons, services may be most appropriate that specifically address symptomatic complaints, combined with a careful consideration of their preinjury history. While such interventions may require the reallocation of health care resources, the costs may, over longer periods, be less than those associated with the use of more standard clinical services (eg, doctor visits) that do not specifically address the underlying medical and psychosocial distress faced by these patients. Clearly, this is a hypothesis requiring further investigation.

CONCLUSIONS

We were able to identify 1 subgroup of persons with unusually high RPQ scores indicative of persisting—that is, unresolved and even worsening—symptomatic complaints. This group has distinctive characteristics, including prior disability, unemployment, a history of drug or alcohol use, prior head injury, and moderate to severe somatic symptoms at the time of injury. The existence of this subgroup suggests that further taxonomic distinctions may be warranted for the larger population of persons with MHI. In addition to those who have sustained demonstrable neuropathology, there may be other, yet to be determined subgroups with distinctive psychological, psychosocial, or neuropsychologic characteristics that also require appropriately designed and targeted interventions. As a model for this approach, the International Mission on Prognosis and Analysis of Clinical Trials in traumatic brain injury presents prognostic models for moderate to severe traumatic brain injuries.[67] Such models are also needed for MHI, even for those subgroups for whom full recovery is an expectation.

References

1. Yang CC, Tu YK, Hua MS, Huang SJ. The association between the postconcussion symptoms and clinical outcomes for patients with mild traumatic brain injury. J Trauma 2007;62:657-63.
2. Heitger MH, Jones RD, Frampton CM, Ardagh MW, Anderson TJ. Recovery in the first year after mild head injury: divergence of symptom status and self-perceived quality of life. J Rehabil Med 2007;39:612-21.
3. Ingebrigtsen T, Waterloo K, Marup-Jensen S, Attner E, Romner B. Quantification of post-concussion symptoms 3 months after minor head injury in 100 consecutive patients. J Neurol 1998;245: 609-12.
4. Whittaker R, Kemp S, House A. Illness perceptions and outcome in mild head injury: a longitudinal study. J Neurol Neurosurg Psychiatry 2007;78:644-6.
5. Sterr A, Herron KA, Hayward C, Montaldi D. Are mild head injuries as mild as we think? Neurobehavioral concomitants of chronic post-concussion syndrome. BMC Neurol 2006;6:7.
6. Vanderploeg RD, Curtiss G, Luis CA, Salazar AM. Long-term morbidities following self-reported mild traumatic brain injury. J Clin Exp Neuropsychol 2007;29:585-98.
7. Cicerone KD, Azulay J. Diagnostic utility of attention measures in postconcussion syndrome. Clin Neuropsychol 2002;16:280-9.
8. Chen JK, Johnston KM, Petrides M, Ptito A. Neural substrates of symptoms of depression following concussion in male athletes with persisting postconcussion symptoms. Arch Gen Psychiatry 2008;65:81-9.
9. McCauley SR, Boake C, Pedroza C, et al. Correlates of persistent postconcussional disorder: DSM-IV criteria versus ICD-10. J Clin Exp Neuropsychol 2008;30:360-79.
10. Cattelani R, Gugliotta M, Maravita A, Mazzucchi A. Postconcussive syndrome: paraclinical signs, subjective symptoms, cognitive functions and MMPI profiles. Brain Inj 1996;10:187-95.
11. van der Naalt J, van Zomeren AH, Sluiter WJ, Minderhoud JM. One year outcome in mild to moderate head injury: the predictive value of acute injury characteristics related to complaints and return to work. J Neurol Neurosurg Psychiatry 1999;66:207-13.
12. Nolin P, Heroux L. Relations among sociodemographic, neurologic, clinical, and neuropsychologic variables, and vocational status following mild traumatic brain injury: a follow-up study. J Head Trauma Rehabil 2006;21:514-26.
13. Haboubi NH, Long J, Koshy M, Ward AB. Short-term sequelae of minor head injury (6 years experience of minor head injury clinic). Disabil Rehabil 2001;23:635-8.
14. Fenton G, McClelland R, Montgomery A, MacFlynn G, Rutherford W. The postconcussional syndrome: social antecedents and psychological sequelae. Br J Psychiatry 1993;162:493-7.
15. Stålnacke BM. Community integration, social support and life satisfaction in relation to symptoms 3 years after mild traumatic brain injury. Brain Inj 2007;21:933-42.
16. Stulemeijer M, van der Werf S, Bleijenberg G, Biert J, Brauer J, Vos PE. Recovery from mild traumatic brain injury: a focus on fatigue. J Neurol 2006;253:1041-7.
17. Carroll LJ, Cassidy JD, Peloso PM, et al. Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehabil Med 2004;43(Suppl):84-105.
18. McCrea M. Mild traumatic brain injury and postconcussion syndrome: the new evidence base for diagnosis and treatment. New York: Oxford Univ Pr; 2008.
19. Hoge CW, McGurk D, Thomas JL, Cox AL, Engel CC, Castro CA. Mild traumatic brain injury in U.S. soldiers returning from Iraq. N Engl J Med 2008;358:453-63.
20. Rohling ML, Meyers JE, Millis SR. Neuropsychological impairment following traumatic brain injury: a dose-response analysis. Clin Neuropsychol 2003;17:289-302.
21. Dikmen S, Machamer J, Winn HR, Temkin NR. Neuropsychological outcome at 1-year post head injury. Neuropsychol 1995; 9:80-90.
22. Ocana M, Jardine A, Ouchterlony D, Feinstein A. How mild is mild head injury? A neuropsychiatric study. Brain Cogn 2000;44: 83-97.
23. McCullagh S, Oucherlony D, Protzner A, Blair N, Feinstein A. Prediction of neuropsychiatric outcome following mild trauma

brain injury: an examination of the Glasgow Coma Scale. Brain Inj 2001;15:489-97.
24. Hoffman RG, Scott JG, Emick MA, Adams RL. The MMPI-2 and closed head injury: effects of litigation and head injury severity. J Forensic Neuropsychol 1999;1:3-13.
25. Kurtz JE, Shealy SE, Putnam SH. Another look at paradoxical severity effects in head injury with the Personality Assessment Inventory. J Pers Assess 2007;88:66-73.
26. Youngjohn JR, Davis D, Wolf I. Head injury and the MMPI-2: paradoxical severity effects and the influence of litigation. Psychol Assess 1997;9:177-84.
27. Greiffenstein M, Baker W. Miller was (mostly) right: head injury severity inversely related to simulation. Legal Criminological Psychol 2006;11:131-45.
28. Ma M, Lindsell CJ, Rosenberry CM, Shaw GJ, Zemlan FP. Serum cleaved tau does not predict postconcussion syndrome after mild traumatic brain injury. Am J Emerg Med 2008;26:763-8.
29. Hofman PA, Stapert SZ, van Kroonenburgh MJ, Jolles J, de Kruijk J, Wilmink JT. MR imaging, single-photon emission CT, and neurocognitive performance after mild traumatic brain injury. Am J Neuroradiol 2001;22:441-9.
30. de Leon MB, Kirsch NL, Maio RF, et al. Baseline predictors of fatigue 1 year after mild head injury. Arch Phys Med Rehabil 2009;90:956-65.
31. Benson RR, Meda SA, Vasudevan S, et al. Global white matter analysis of diffusion tensor images is predictive of injury severity in traumatic brain injury. J Neurotrauma 2007;24:446-59.
32. Huisman TA, Schwamm LH, Schaefer PW, et al. Diffusion tensor imaging as potential biomarker of white matter injury in diffuse axonal injury. Am J Neuroradiol 2004;25:370-6.
33. Kraus MF, Susmaras T, Caughlin BP, Walker CJ, Sweeney JA, Little DM. White matter integrity and cognition in chronic traumatic brain injury: a diffusion tensor imaging study. Brain 2007; 130:2508-19.
34. Rutgers DR, Fillard P, Paradot G, Tadie M, Lasjaunias P, Ducreux D. Diffusion tensor imaging characteristics of the corpus callosum in mild, moderate, and severe traumatic brain injury. Am J Neuroradiol 2008;29:1730-5.
35. Niogi SN, Mukherjee P, Ghajar J, et al. Extent of microstructural white matter injury in postconcussive syndrome correlates with impaired cognitive reaction time: a 3T diffusion tensor imaging study of mild traumatic brain injury. Am J Neuroradiol 2008;29: 967-73.
36. Miles L, Grossman RI, Johnson G, Babb JS, Diller L, Inglese M. Short-term DTI predictors of cognitive dysfunction in mild traumatic brain injury. Brain Inj 2008;22:115-22.
37. Mooney G, Speed J, Sheppard S. Factors related to recovery after mild traumatic brain injury. Brain Inj 2005;19:975-87.
38. Suhr JA, Gunstad J. Postconcussive symptom report: the relative influence of head injury and depression. J Clin Exp Neuropsychol 2002;24:981-93.
39. McCauley SR, Boake C, Levin HS, Contant CF, Song JX. Postconcussional disorder following mild to moderate traumatic brain injury: anxiety, depression, and social support as risk factors and comorbidities. J Clin Exp Neuropsychol 2001;23:792-808.
40. Spinos PC, Sakellaropoulos GC, Deli AG, Maraziotis TG, Constantoyannis CD. The low rate of chronic postconcussion symptoms following mild head injuries in Greeks: a prospective study. Eur J Neurol 2007;14(Suppl 1):165-301.
41. Uomoto JM, Fann JR. Explanatory style and perception of recovery in symptomatic mild traumatic brain injury. Rehabil Psychol 2004;49:334-7.
42. Ferrari R, Obelieniene D, Russell A, Darlington P, Gervais R, Green P. Symptom expectation after minor head injury: a comparative study between Canada and Lithuania. Clin Neurol Neurosurgery 2001;103:184-90.
43. Davis CH. Self-perception in mild traumatic brain injury. Am J Phys Med Rehabil 2002;81:609-21.
44. Mittenberg W, DiGiulio DV, Perrin S, Bass AE. Symptoms following mild head injury: expectation as aetiology. J Neurol Neurosurg Psychiatry 1992;55:200-4.
45. Gunstad J, Suhr JA. Cognitive factors in postconcussion syndrome symptom report. Arch Clin Neuropsychol 2004;19:391-405.
46. Binder LM, Rohling ML. Money matters: a meta-analytic review of the effects of financial incentives on recovery after closed-head injury. Am J Psychiatry 1996;153:7-10.
47. Miller LJ, Donders J. Subjective symptomatology after traumatic head injury. Brain Inj 2001;15:297-304.
48. Pagulayan KF, Temkin NR, Machamer J, Dikmen SS. A longitudinal study of health-related quality of life after traumatic brain injury. Arch Phy Med Rehabil 2006;87:611-8.
49. McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. JAMA 2003;290:2556-63.
50. Belanger HG, Vanderploeg RD. The neuropsychological impact of sports-related concussion: a meta-analysis. J Int Neuropsychol Soc 2005;11:345-57.
51. McClincy MP, Lovell MR, Pardini J, Collins MW, Spore MK. Recovery from sports concussion in high school and collegiate athletes. Brain Inj 2006;20:33-9.
52. Mickeviciene D, Schrader H, Obelieniene D, et al. A controlled prospective inception cohort study on the post-concussion syndrome outside the medicolegal context. Eur J Neurol 2004;11: 411-9.
53. Schretlen DJ, Shapiro AM. A quantitative review of the effects of traumatic brain injury on cognitive functioning. Int Rev Psychiatry 2003;15:341-9.
54. McLean SA, Kirsch NL, Tan-Schriner CU, et al. Health status not head injury predicts concussion symptoms after minor injury. Am J Emerg Med 2009;27:182-90.
55. Horner MD, Selassie AW, Lineberry L, Ferguson PL, Labbate LA. Predictors of psychological symptoms 1 year after traumatic brain injury: a population-based, epidemiological study. J Head Trauma Rehabil 2008;23:74-83.
56. Luis CA, Vanderploeg RD, Curtiss G. Predictors of postconcussion symptom complex in community dwelling male veterans. J Int Neuropsychol Soc 2003;9:1001-15.
57. Kashluba S, Paniak C, Casey JE. Persistent symptoms associated with factors identified by the WHO Task Force on mild traumatic brain injury. Clin Neuropsychol 2008;22:195-208.
58. Kay T, Newman B, Cavallo M, Ezrachi O, Resnick M. Toward a neuropsychological model of functional disability after mild traumatic brain injury. Neuropsychol 1992;6:371-84.
59. McLean SA, Clauw DJ. Predicting chronic symptoms after an acute "stressor"—lessons learned from 3 medical conditions. Med Hypotheses 2004;63:653-8.
60. American Congress of Medical Rehabilitation. Definition of mild traumatic brain injury. J Head Trauma Rehabil 1993;8:86-7.
61. Whiteneck G, Mellick D, Harrison-Felix C, Brooks CA, Terrill MS, Noble K. Colorado traumatic brain injury and follow up system databook. Englewood: Craig Hospital; 2001.
62. King NS, Crawford S, Wenden FJ, Moss NE, Wade DT. The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. J Neurol 1995;242:587-92.

63. Smith-Seemiller L, Fow NR, Kant R, Franzen MD. Presence of post-concussion syndrome symptoms in patients with chronic pain vs mild traumatic brain injury. Brain Inj 2003;17:199-206.
64. Ponsford J, Willmott C, Rothwell A, et al. Factors influencing outcome following mild traumatic brain injury in adults. J Int Neuropsychol Soc 2000;6:568-79.
65. Paniak C, Toller-Lobe G, Reynolds S, Melnyk A, Nagy J. A randomized trial of two treatments for mild traumatic brain injury: 1 year follow-up. Brain Inj 2000;14:219-26.
66. Mittenberg W, Canyock EM, Condit D, Patton C. Treatment of post-concussion syndrome following mild head injury. J Clin Exp Neuropsychol 2001;23:829-36.
67. Murray GD, Butcher I, McHugh GS, et al. Multivariable prognostic analysis in traumatic brain injury: results from the IMPACT study. J Neurotrauma 2007;24:329-37.

Supplier

a. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.