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ONE-YEAR FOLLOW-UP OF MILD TRAUMATIC BRAIN INJURY: POST-CONCUSSION SYMPTOMS, DISABILITIES AND LIFE SATISFACTION IN RELATION TO SERUM LEVELS OF S-100B AND NEURONE-SPECIFIC ENOLASE IN ACUTE PHASE

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Objective: **To investigate, in patients with mild traumatic brain injury, serum concentrations of S-100B and neurone-specific enolase in acute phase and post-concussion symptoms, disabilities and life satisfaction 1 year after the trauma.**
Design: **Prospective study.**
Patients: **Eighty-eight patients (age range 18–87 years).**
Methods: **Blood samples were taken on admission and about 7 hours later. At follow-up 15±4 months later, the patients filled in questionnaires about symptoms (Rivermead Post Concussion Symptoms), disability (Rivermead Head Injury Follow-up) and life satisfaction (LiSat-11).**
Results: **Concentrations of S-100B and neurone-specific enolase were regularly increased in the first blood sample. Of the 69 patients participating in the follow-up, 45% reported post-concussion symptom, 48% exhibited disability and 55% were satisfied with "life as a whole". In comparison with the "sick-leave" situation on admission to hospital, 3 patients were on sick-leave at the time of follow-up because of the head trauma. Stepwise forward logistic regression analysis revealed a statistically significant association ($p<0.05$) between disability and S-100B and dizziness.**
Conclusion: **In spite of frequent persistent symptoms, disabilities and low levels of life satisfaction, the sick-leave frequency was low at follow-up. The association between S-100B and disability supports the notion that long-term consequences of a mild brain injury may partly be a result of brain tissue injury.**

Key words: traumatic brain injury, head trauma, brain concussion, biochemical marker, S-100 proteins, life satisfaction, post-concussion symptoms.

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INTRODUCTION

The incidence of head injuries requiring hospitalization is 250–300/100,000/year (1). A majority (80–85%) are mild head injuries (2) and this is a matter for major general concern since a great number of patients (up to 80%) may suffer from persistent symptoms (e.g. headache, fatigue, dizziness and cognitive deficits) which interfere with the patient's return to work and resumption of leisure activities (3, 4). Much effort has been devoted to evaluate recovery potential after mild head injury and to identify which patients run a risk of developing persistent symptoms. Some of the risk factors that have been shown to be associated with poor outcome are female gender, ongoing litigation, alcohol abuse, prior head injury and age over 40 years (5, 6).

During the last few years, neurobiochemical markers of brain tissue damage (e.g. S-100B, neurone-specific enolase, glial fibrillary acidic protein, myelin-specific protein, etc. (7)) have attracted growing interest with respect to both diagnostic and prognostic purposes for patients with traumatic brain injuries. Accordingly, increased serum concentrations of, for example, S-100B (a calcium-binding protein present in high concentrations in glial cells) and neurone-specific enolase (NSE: a cytoplasmatic enzyme occurring predominantly in neurones) have been demonstrated to reflect the presence and severity of brain tissue damage in acute head injuries (8). However, the specificity of S-100B as a marker of brain tissue injury has been questioned, as increased serum levels of S-100B are also found in patients with fractures (9) and in healthy subjects in association with sports practice, e.g. playing ice hockey, soccer and basketball (10, 11). Furthermore, in studies of clinical outcome, both S-100B and NSE have been demonstrated to be of prognostic value with respect to persistent post-concussion symptoms and impaired cognitive functioning after mild traumatic brain injury (MTBI). However, in all these studies the follow-up times were rather short (no longer than 3 months) and data are scarce on the predictive value of these markers for long-term outcome (1 year or more) with respect to disability and life satisfaction.

It was decided therefore to carry out a prospective study of patients with MTBI in order to investigate serum concentrations of S-100B and NSE in the acute phase, and post-concussion

Table I. *Characteristics of 88 patients with mild traumatic brain injury*

Characteristic	n (%)
Gender	
Women	35 (39.8)
Men	53 (60.2)
Age (years)	40.9 ± 19.5
Employment	
Employed or student	61 (69.3)
Unemployed – seeking work	2 (2.3)
Retired	14 (15.9)
Sick-leave	3 (3.4)
Unknown	8 (9.1)
Previous concussions	
Yes	29 (33.0)
No	31 (35.2)
Unknown	28 (31.8)
Glasgow coma scale	
15	76 (86.4)
14	11 (12.5)
13	1 (1.1)
Accidental data (%)	
Work circumstances	20 (22.7)
Leisure time	65 (73.9)
Unknown	3 (3.4)
Alcohol ingestion	24 (27.3)
External cause	
Indoor falls	12 (13.6)
Outdoor falls	24 (27.3)
Falls from height	3 (3.4)
Bicycle	28 (31.8)
Horseback riding	5 (5.7)
Assault	2 (2.3)
Vehicle-related	2 (2.3)
Sports-related	7 (8.0)
Other accident	2 (2.3)
Unknown	3 (3.4)
Symptoms on admission	
Dizziness	14 (15.9)
Nausea/vomiting	37 (42.0)
Headache	3 (39.8)
Fatigue	17 (19.3)
Light sensibility	2 (2.3)
Double vision	6 (6.9)
Pain	33 (37.9)
Depression	3 (3.4)
Bad concentration	1 (1.1)
Loss of consciousness	54 (61.4)
Mean duration (minutes)	3.8 ± 5.7 ($n = 43$)
Anterograde amnesia	70 (79.5)
Mean duration (minutes)	146 ± 308 ($n = 64$)
Fractures (number of patients)	13 (14.8)
Costal fractures	3
Clavicle fractures	3
Facial fractures	5
Fracture of the pelvis	1
Fracture of a thoracic vertebrae	1
Symptoms at discharge	
Dizziness	16 (18.2)
Nausea/vomiting	5 (5.7)
Headache	27 (30.7)
Fatigue	13 (14.8)
Light sensibility	1 (1.1)
Noise sensibility	1 (1.1)
Poor memory	1 (1.1)
Weak	3 (3.4)
Pain	18 (20.5)

symptoms, disabilities and life satisfaction 1 year after the trauma.

METHODS

Patients and procedure

Patients with MTBI, (Glasgow Coma Scale (GCS) 13–15, loss of consciousness less than 30 minutes) were enrolled at Umeå University Hospital (between June 1997 and June 1999). Inclusion criteria were: blunt head trauma, age over 18 years, GCS 13–15 on arrival to the emergency department and diagnosis of concussion/commotio cerebri/ mild head injury/MTBI leading to hospitalization for observation. Sociodemographic, accidental and clinical characteristics and symptoms of the patients are presented in Table I. Management routines of patients with MTBI in this hospital consisted of an examination by the emergency physician (regularly a general surgeon), who then made decisions about computerized tomography (CT) scan and/or hospitalization. A CT scan was performed on 10 patients (11%) and was normal in all cases. Once the decision about hospitalization was taken, the patients were asked to participate in the present study. Unfortunately, not all patients eligible for the study were asked about participation due to, on occasions, excessive workload among the emergency department personnel. Data about trauma history, symptoms on admission and on discharge, employment status, etc. were collected from the ongoing injury and trauma register, ambulance and hospital records. The patients were also contacted by a research nurse and underwent a structural interview before being discharged from the hospital.

Out of a total of 98 patients who gave their informed consent to participate in the study, complete data on acute phase were obtained for 88 patients (except for 2 blood samples) (53 men and 35 women, Table I). This paper reports on these 88 patients.

The study was approved by the ethics committee of Umeå University.

Follow-up

A follow-up was carried out by post 15 ± 4 months after the trauma, using a set of questionnaires for the assessment of disabilities (Rivermead Head Injury Follow-up Questionnaire (RHFUQ) (12), life satisfaction (LiSat-11) (13) and presence or absence of post-concussion symptoms (items of Rivermead Post Concussion Symptoms Questionnaire, RPQ (14) were employed). An additional questionnaire comprising questions about sick-leave, employment, concussion during the previous year and leisure activities was also administered. One patient abstained from responding to LiSat-11.

Altogether, 69 patients (78%, 39 men and 30 women) participated in the follow-up. The population of participants ($n = 69$) and non-participants ($n = 19$) were compared (variables: age, gender, employment, previous concussion, external cause of the accident, symptoms on admission and at discharge, loss of consciousness, amnesia and alcohol intake) and they differed only with respect to alcohol intake (i.e. a significantly larger proportion of the non-participants had been under the influence of alcohol at the time of trauma, $p = 0.016$).

Laboratory procedure

Venous blood samples were taken (3.0 ± 2.2 hours post-trauma) as soon as the patients gave their informed consent and again about 7 hours later (10.3 ± 3.3 hours) for analysis. In this study the analysis of S-100B and NSE are shown. The blood was allowed to clot and was kept at 5°C until centrifugation. The sera were frozen and kept at −78°C until analysis.

All samples were analysed with respect to S-100B as 1 batch using immunoluminometric assays (LIAISON Sangtec 100, Sangtec Medical, Bromma, Sweden), which measure A1B isoforms (present mainly in glial cells) and BB isoforms (occurring mostly in glial cells and Schwann cells) of the protein S-100 by assessing its B-subunit as defined by 3 monoclonal antibodies. The detection limit of the test is 0.02 μg/l. It has been demonstrated that 95% of healthy men and women have serum concentrations below 0.15 μg/l (15). The laboratory was blind to the aim of the study. NSE was determined with an immunoluminometric assay based on monoclonal antibodies (LIAISON NSE, Sangtec Medical, Bromma, Sweden). The detection limit of the kit is less than 1.0 μg/l.

The analyses results of the first blood sample (i.e. taken on admission) are denoted S-100B/1, and NSE/1 and the results obtained from the second blood sample (i.e. taken about 7 hours after the sample on admission) are denoted S-100B/2 and NSE/2.

Statistical analysis

The data were analysed with SPSS, version 11.5 for Windows. Data are reported as means ± SD unless indicated otherwise. A statistical data evaluation was performed with non-parametric tests as some of the samples were rather small and/or not normally distributed. Thus, the Mann-Whitney *U* test was used for the comparison of continuous variables, Wilcoxon's signed-rank test for the study of paired observation variables. Spearman's correlation coefficients were calculated for the analysis of bivariate correlations.

In previous studies, symptoms on admission (dizziness, headache and nausea) and serum concentrations of S-100B shortly after the trauma were shown possibly to serve as predictors of long-term persistent symptoms (16, 17). Therefore, it was decided to use these factors as independent variables in logistic regression analyses. The dependent variables (i.e. presence or absence of post-concussion symptoms, presence or absence of disabilities, high and low level of life satisfaction at follow-up) were dichotomized and coded as a binary variable (1 and 0, respectively). Univariate analysis was performed and variables showing an association $p < 0.1$ were then used for stepwise forward logistic regression analysis. The entry limit was set at $p < 0.05$ and $p > 0.10$ for removal limit. The results of the logistic regression analysis are presented as odds ratio (OR), which indicates an increased (OR > 1) or decreased (OR < 1) likelihood of the event (coded as 1) occurring. The reliability of the OR is expressed as 95% confidence interval (CI). The level of statistical significance was set at $p < 0.05$.

RESULTS

Serum concentrations of S-100B and neurone-specific enolase

Figure 1 shows serum concentrations of S-100B and NSE. A majority of the patients showed higher concentrations of both S-100B (78%) and NSE (89%) in the first blood sample taken 3.0 ± 2.2 hours after injury (sample 1: S-100B/1 0.363 ± 0.333 µg/l; NSE/1 10.93 ± 4.12 µg/l) compared with the second blood sample obtained 10.3 ± 3.3 hours after injury (sample 2: S-100B/2 0.192 ± 0.134 µg/l; NSE/2 7.77 ± 4.52 µg/l). Statistical analysis revealed a significant difference between the first and second sample, for both markers ($p < 0.001$). Neither the concentration of S-100B nor that of NSE differed between male and female patients in the first blood sample (S-100B/1, $p = 0.389$; NSE/1, $p = 0.120$), while in the second blood sample the serum levels of S-100B for female patients were higher (S-100B/2, $p = 0.021$; NSE/2, $p = 0.225$). S-100B levels were higher in patients older than 65 years (S-100B/1: $p = 0.025$; S-100B/2: $p = 0.008$) in comparison with patients younger than 65 years. No statistically significant difference with respect to S-100B and NSE was found when patients with fractures were compared with the patients without any fracture (S-100/1: $p = 0.303$; S-100/2: $p = 0.704$; NSE/1: $p = 0.189$; NSE/2: $p = 0.064$).

S-100B and NSE serum concentrations were found to be weakly correlated with each other (sample 1: $r = 0.258$, $p = 0.016$; sample 2: $r = 0.212$, $p = 0.049$).

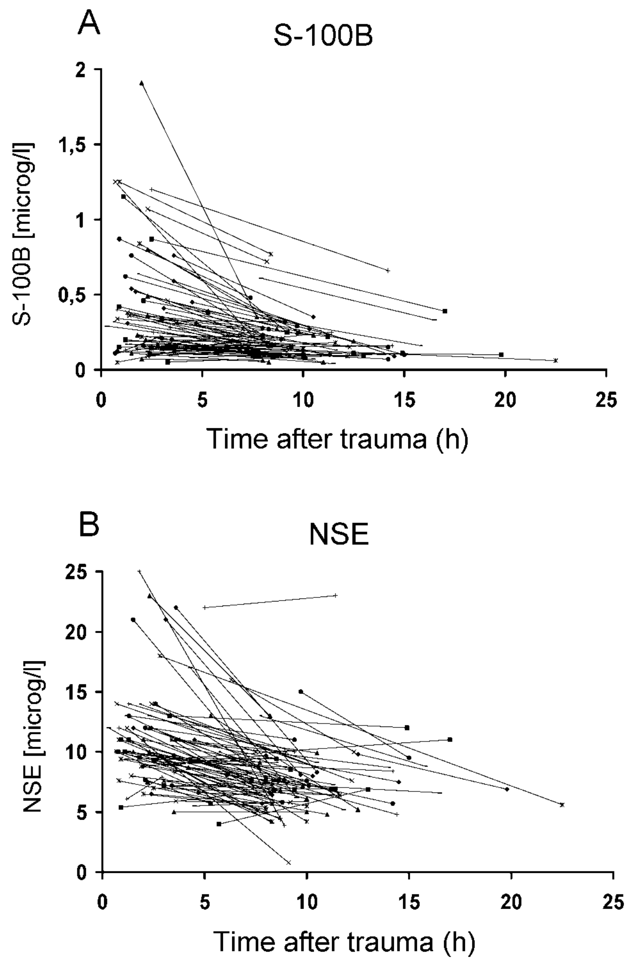

Fig. 1. Serum concentrations of (a) S-100B and (b) neurone-specific enolase (NSE). Symbols representing each patient are connected by lines.

Occurrence of post-concussion symptoms

The presence of post-concussion symptoms was assessed using questions in the RPQ (see Methods). At the time of the follow-up, 31 patients (45%) showed at least 1 or more of the post-concussion symptoms. At follow-up 2 patients reported the presence of 13 and 14 symptoms, respectively, 7 patients reported 6–10 symptoms and 22 subjects reported 1–5 symptoms, while symptoms were absent in 38 (55%) patients. One patient, a man aged 72 years, suffered from a subdural haematoma. He was re-admitted and operated on 3 weeks after the trauma.

In an attempt to find factors that could possibly be of importance for the prediction of persistent symptoms after MTBI, we performed logistic regression analysis. To this end, patients who reported the occurrence of 1 or more symptoms at follow-up were chosen as a dependent variable and coded as a binary variable (1 = patients with 1 symptoms or more, 0 = patients with no symptoms). No statistically significant association was found between persistent symptoms at follow-up and S-100B/1 levels, nausea, dizziness and headache in the acute phase.

Level of disability

The level of disability at follow-up was measured by the RHFUQ. In total, 33 patients (48%) reported at least 1 disability

Table II. *Frequency of occurrence (%,* n = *68) of self-reported levels of satisfaction with life as a whole and with 10 different life domains and percentages of patients (*n = *68) marking "very satisfied"/"satisfied" (last column) for each specific item of LiSat-11*

Item	Very satisfied (%)	Satisfied (%)	Rather satisfied (%)	Rather dissatisfied (%)	Dissatisfied (%)	Very dissatisfied (%)	Mean (SD)	Satisfied/Very satisfied (%)
Life as a whole	10.1	44.9	27.5	7.2	5.8	2.9	4.4 (1.1)	55.0
Vocation	4.3	31.9	31.9	13.0	10.1	4.3	3.4 (1.2)	36.2
Economy	11.6	24.6	30.4	17.4	7.2	7.2	3.4 (1.4)	36.2
Leisure	11.6	37.7	20.3	14.5	5.8	8.7	4.1 (1.4)	49.3
Contacts	15.9	39.1	26.1	10.1	4.3	2.9	4.4 (1.2)	55.0
Sexual life	8.7	33.3	21.7	14.5	7.2	7.2	4.0 (1.4)	42.0
ADL	50.7	37.7	5.8	2.9	0	1.4	5.3 (0.9)	88.4
Family life	27.5	34.8	15.9	4.3	8.7	4.3	4.6 (1.4)	62.3
Partner	29.0	30.4	13.0	7.2	4.3	7.2	4.5 (1.5)	59.4
Somatic health	27.5	36.2	15.9	7.2	8.7	2.9	4.6 (1.4)	63.7
Psychological health	27.5	36.2	17.4	8.7	5.8	2.9	4.6 (1.3)	63.7

ADL = activities of daily living.

on the RHFUQ. The mean RHFUQ-score was 6.5 ± 10.2 (range: 0–38, maximum disability score 40). The most frequently reported changes were on the disability items "finding work more tiring" (reported by 24 patients), "ability to maintain previous work load/standard" (22 patients) and "ability to enjoy previous leisure activities" (21 patients). In a logistic regression analysis of the RHFUQ, patients exhibiting any disability were chosen as a dependent variable and coded as a binary variable (1 = patients with disabilities, 0 = patients with no disabilities). Stepwise forward logistic regression analysis resulted in 3 steps and in the final equation the following variables were entered with statistically significant effects: S-100/1 (OR = 10.0 per 1 μg concentration increase, CI 1.46–68.91, $p = 0.019$), "dizziness on admission" (OR = 4.2, CI 1.01–17.32, $p = 0.048$), or close to significant effect: "nausea on admission" (OR = 2.9, CI 0.99–8.54, $p = 0.053$).

Life satisfaction

At follow-up, life satisfaction was assessed using the LiSat-11 questionnaire (Table II). The relative distribution of the patients among the 6 different levels of life satisfaction is given: "very satisfied" and "satisfied" were pooled together in accordance with previous studies with LiSat-11 (13) to give an overall assessment of life satisfaction and the pooled frequencies are displayed (Table II). Only 36% of the patients ($n = 69$) were either "very satisfied" or "satisfied" with "vocation" and "economy" and only 42% and 49% of the patients reached this level of satisfaction for "sexual life" and "leisure", respectively. The mean total LiSAt-11 score for all the 69 patients was 46.1 ± 10.8 (range 12–62; maximum possible score = 66). There was a statistically significant negative correlation between the total score of LiSat-11 and the total score of RHFUQ ($r = -0.514$, $p < 0.001$), indicating that life satisfaction level decreased with increasing disability. Logistic regression analysis was also carried out (dependent variable: patients rating 6 or more items of LiSat-11 as "very satisfied or satisfied" = 1, patients rating 5 or less variables of LiSat-11 in a similar way = 0). The univariate analysis showed that statistically significant effect was only obtained for, "nausea on admission" (OR = 0.2, CI: 0.06–0.53, $p = 0.002$), implying that presence of "nausea on admission" decreased the probability to exhibit high levels of life satisfaction.

Sick-leave

A total of 31 patients (out of 69 participating in the follow-up) were on sick-leave for 1–2 days after the discharge from the hospital. Longer periods of sick-leave were generally due to orthopaedic injuries (mainly fractures, see Table I). One year after the trauma 5 patients were on sick-leave, 3 of whom (2 men, 1 woman) because of the head injury (remaining causes of sick-leave: low back pain and alcohol abuse). Most patients (49 patients, 71%) were working or studying at the time of the follow-up, 12 subjects (17%) were pensioners and for 3 patients (4%) sick-leave status/working situation was not reported. Thus, in comparison to the "sick-leave" situation on admission to hospital (see Table I), 3 patients (4%) were on sick-leave at the time of the follow-up because of the MTBI.

DISCUSSION

The present study shows that, on admission to hospital, the majority of patients had increased serum levels of S-100B and NSE, compared with serum levels a few hours later. Persistent post-concussion symptoms were frequently reported and 45% of the patients who participated in the follow-up still reported some symptom 1 year after injury.

Patients

Altogether, 69 (i.e. 78%) of the 88 patients completed the follow-up fully and it seems therefore that the data are representative for the total population of patients in the present study. The percentage of patients who participated in the follow-up appears also to be comparable with other studies of patients with mild head injury and 1-year follow-up (e.g. 35–88% (18, 19). However, the inclusion of patients was not performed randomly (see Methods), and this may have biased the results.

Instruments

Serum concentrations of S-100B and NSE were assessed using standard commercially available methods (see Methods). Both S-100B and NSE are considered to be biochemical markers of brain tissue injury (8). However, it appears that both these markers have limited specificity as "markers of brain tissue injury", since they occur in extra-cerebral tissues (20) and since serum concentrations of S-100B, at any rate, may be increased by non-cerebral injuries (e.g. in patients with fractures (9) and even during exercise and sport practice without apparent significant head trauma (10, 11). Therefore, the contribution from extra-cerebral sources to the serum increases of S-100B in the present study cannot be disregarded.

Serum levels of S-100B and NSE

Serum concentrations of S-100B on admission are in accordance with the levels reported after mild head injury in other studies (e.g. 21). For a majority of the patients both S-100B and NSE decreased with time after the injury and were lower in the second blood sample (obtained about 10.3 hours after injury) in comparison with the first blood sample (taken about 3.0 hours after injury), a finding which is similar to several previous studies (e.g. 22). Moreover, S-100B and NSE serum concentrations were statistically significantly (yet weakly) correlated with each other (sample 1: $r = 0.258$, $p = 0.016$; sample 2: $r = 0.212$, $p = 0.049$). Accordingly, simultaneous increases in S-100B and NSE were regularly encountered, and this may either indicate damage of both glial and neuronal cells or be a result of complex neuronal-glial interactions (8).

Post-concussion symptoms

At follow-up 1 year after the injury a total of 31 patients (45%) reported some symptom related to the head trauma. This is within the range of figures reported in previous studies (20–80% (4, 23)). The most common symptom at follow-up was headache (reported by 15 patients), followed by dizziness and fatigue (both reported by 13 patients). The order of frequency of occurrence of these symptoms is roughly compatible with previous studies using 1-year follow-up (4, 23). It should be recalled in this context that the post-concussion symptoms are not exclusively encountered in patients after mild head trauma and that they are also frequently reported by apparently healthy people (24) and, for example, in patients with chronic pain (25).

In several studies focusing on the relationship between persistent post-concussion symptoms in patients with MTBI and biochemical markers of brain injury, accidental data and early post-trauma symptoms and signs, the authors came to the conclusion that data on S-100B shortly after the trauma (17), combination of S-100B data and specific symptoms (e.g. dizziness and headache (17), dizziness, headache and nausea (16)), duration of post-traumatic amnesia alone (4) or duration of post-traumatic amnesia together with other measures (26), might serve to predict long-term persistent symptoms, that is to predict which patients are at risk of developing post-concussion disorder. Thus, using this study design, we were unable to demonstrate any significant association between serum concentration levels of S-100B, NSE and the probability of exhibiting the presence of post-concussion symptoms at 1 year after trauma. In a recent study, Nygren de Boussard et al. (27) were likewise unable to demonstrate any correlation between serum levels of S-100B and symptoms according to the RPQ 1–14 days post-injury (27).

Disabilities

Presence of any disability was reported by 33 patients (48%), and this corresponds well with the figure (48–56%) obtained for patients with mild head injury in a study with a 6-month follow-up (28). Our finding of the most frequently reported disability item, i.e. "finding work more tiring" is also in accordance with this study. Disability involving leisure activities was also common in our study (11 patients, 30%), indicating that there was also an effect on less demanding activities with respect to performance and achievement than professional life/work. Interestingly, in contrast to these rather frequently reported disabilities involving both professional and private life, only 3 patients (2 men and 1 woman) were on sick-leave at follow-up. We dichotomized the patients into those showing disability (1) and those without any disability (0) and then performed a multiple logistic regression analysis. This analysis demonstrated that increased concentrations of S-100B/1 ($p = 0.019$), the presence of "dizziness on admission" ($p = 0.048$) and "nausea on admission" ($p = 0.053$) increased the probability of developing a persistent disability. These results indicate that it may be meaningful to explore further the possibilities of combining information on symptoms with information on biochemical markers shortly after a mild head injury in order to find more practical and valid instruments for the prediction of outcome in patients with mild head injury.

Life satisfaction

Altogether only 55% of the patients reported themselves to be "very satisfied/satisfied" on the item "life as a whole" at follow-up. The corresponding figures were even lower for "vocation" (36%), "leisure" (49%) or "economy" (36%). These scores are clearly lower than the population-based reference values of the LiSat-11 described by Fugl-Meyer et al. (13) (i.e. "life as a whole", 72%; "vocation", 54%; "leisure", 58%). Thus, it appears that our sample of patients with MTBI reported decreased levels of life satisfaction in comparison with a large Swedish reference population (2533 subjects) (13). Similarly, ratings of quality of life of a cohort of patients with MTBI were found to be lower than those of a gender- and age-matched control group by Emanuelson and co-workers (19) using SF-36 (a standardized health survey) with respect to the quality of life 1-year post-trauma.

A negative correlation was demonstrated between the total score of LiSat-11 and the total disability score (as assessed with RHFUQ, $r = -0.514$, $p < 0.001$). This negative correlation appears to depict the fact that decreased life satisfaction probably reflects increased disability levels and it may also indicate a need for rehabilitation measures, in spite of a low frequency of occurrence of sick-leave and irrespective of the pre-trauma health state of the patients. The present study provides results that indicate that the MTBI patients of our study are very rarely on sick-leave in spite of considerable symptoms and disabilities with accompanying lower levels of life satisfaction. Accordingly, it appears that litigation or malingering did not play a major role in the development of complaints and impairments after MTBI in our patients, which is in agreement with a recently published study (29). Also, a multivariate logistic regression analysis disclosed statistically significant association between life satisfaction and "nausea on admission" ($p = 0.02$) showing that the occurrence of "nausea on admission" decreased the probability of exhibiting high levels of life satisfaction.

Concluding remarks

As a whole, the findings of this paper provide support for the idea that brain tissue injury is involved in the genesis of persistent disabilities in MTBI. Moreover, the biochemical marker for brain damage, level of S-100B shortly after trauma, appears to be a much more promising tool for prediction of disability than for prediction of persistent symptoms after MTBI, and this may be useful in the early singling out of patients in need of rehabilitation after head trauma.

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