COPING STYLES, CORTISOL REACTIVITY, AND PERFORMANCE IN A VIGILANCE TASK OF PATIENTS WITH PERSISTENT POSTCONCUSSIVE SYMPTOMS AFTER A MILD HEAD INJURY

N. BOHNEN, J. JOLLES

Department of Neuropsychology & Psychobiology, University of Limburg, Maastricht, The Netherlands

A. TWIJNSTRA

Department of Neurology, University Hospital Maastricht, The Netherlands

R. MELLINK and J. SULON

Laboratoire des Steroides, Centre Hospitalier Universitaire Sart Tilman, Liege, Belgium

(Received August 25, 1991)

Some patients experience persistent postconcussive symptoms (PCS) after a mild head injury (MHI). According to the coping hypothesis, PCS result from the increased stress that head-injured patients experience when they are not able to cope with environmental demands. This study examined the coping ability and cortisol reactivity of MHI patients with and without PCS and in uninjured controls. Patients with PCS 12–34 months after injury were individually matched with MHI patients without PCS (N = 11) and healthy controls (N = 11) for the time elapsed since the injury, age, sex, education, and IQ. First, we found that patients with PCS reported being less able to cope with problems. These patients appeared to be inferior in active problem solving and had a more depressive attitude toward problems than subjects of the two control groups. Second, we found no differences between the three groups in the mean cortisol response during a vigilance task. These results only partly support the coping hypothesis. With respect to cognitive performance, we found that decrements in a vigilance task were related to an increased cortisol response during this task, especially in apparently "recovered" (asymptomatic) MHI patients. The latter finding may point to an increased cognitive vulnerability of apparently recovered MHI patients when exposed to a CNS stressor.

Keywords: Cognitive impairment, cortisol, mild head injury, post-concussive symptoms, stress.

Patients with mild head injury (MHI) may complain of a number of postconcussive symptoms (PCS), including headache, fatigue, and cognitive problems (Binder 1986; Lishman, 1988). Evidence is accumulating to indicate that even mild to moderate head injury may produce subtle cognitive deficits (Hugenholtz, Stuss, Stethem & Richard, 1988) and there is circumstantial evidence that the cognitive difficulties are especially experienced when MHI patients have to perform information processing and attention tasks under time pressure or stress (Gronwall & Wrightson, 1974). Patients may have a decreased work performance, become less efficient, make mis-

Correspondence to: N. Bohnen, Department of Neuropsychology and Psychobiology, University of Limburg, P.O. Box 616, 6200 MD Maastricht, The Netherlands.
takes, and exhaust themselves trying to keep up. Although patients may recover quickly after MHI, there is a subgroup of patients who complain of persisting PCS beyond the first weeks of recovery (Gronwall & Wrightson, 1974). Recently, Leininger, Grantling, Kreutzer, and Peck (1990) found that MHI patients with persistent PCS had neuropsychological deficits in comparison with nonconcussed control subjects. These findings indicate that patients with subjective disability after MHI may have demonstrable objective deficits. As an explanation for the persistence of symptoms in some patients after head injury, Van Zomeren (1981) formulated the "coping hypothesis" and suggested that PCS (in his terms "intolerance" or "neurotic" type of complaints) may result from a chronically increased mental effort by patients to compensate for posttraumatic cognitive deficits. Thus, it is possible that head-injured patients have an impaired adaptive ability and increased perceived stress following head injury with their symptoms hypothesized as similar to those of stress reactions (Hinkeldey & Corrigan, 1990).

Coping can be defined as an individual's cognitive and behavioral effort to master demands and conflicts (Holroyd & Lazzaras, 1982). Coping responses represent the specific actions that people take to deal with a given problem or stressor; for example, by talking it over with others, ignoring the situation, or taking direct action to solve the problem (Menaghan, 1982; Bohnen, Nicolson, Sulon & Jolles, 1991). Little has been reported in the literature about the coping strategies used by head-injured patients. The few studies of coping and head injury only concern severely head-injured patients (Moore, Stambrook & Peters, 1989; Hinkeldey & Corrigan 1990), and provide evidence that less effective coping strategies contribute to patients' posttraumatic symptoms.

Taken together, there is circumstantial evidence to suggest that posttraumatic stress reactions contribute to the pathogenesis of PCS when head-injured patients are unable to cope with environmental demands. Although there is evidence of decreased coping ability after the injury, there are very few studies that have operationalized concepts like "mental effort" and "stress." For example, Brouwer and Woffelaar (1985) found no performance-related increase in heart rate variability in head-injured patients during a vigilance task in comparison with control subjects, although the authors commented that there were baseline differences between the groups before the start of the task (see also Van Zomeren, 1981). The secretion of cortisol into body fluids has often been used as a measure of the biological response to stress (Hubert and De Jong, 1989). Bohnen et al. (1991) found a relationship between salivary cortisol secretion and individual coping ability during mental stress. A possible involvement of the stress hormone cortisol in tasks involving continuous mental effort is suggested by the study of Bohnen, Houx, Nicolson, and Jolles (1990), who demonstrated a negative relationship between increased cortisol reactivity and attentional performance. There is no information available on the role of stress hormones in head-injured patients and the relationship to postconcussive symptoms and cognitive performance. It is possible that within the context of the coping hypothesis, MHI patients with persisting PCS have a reduced coping ability and may respond with an increased cortisol secretion during a mental task.

The first aim of the present study, therefore, was to test the hypothesis that patients with persisting postconcussive symptoms after MHI have a less effective coping ability than matched, asymptomatic MHI patients and nonconcussed controls. A second aim of the study was to test the hypothesis that MHI patients with postconcussive complaints have an increased stress response, in terms of cortisol reactivity, during cognitive performance in a vigilance task in comparison with the two control groups.
TABLE 1
Mean Age, Time after the Trauma (Months), & Educational Level (Verhage, 1964) and IQ (Luteijn et al. 1983) of Patients with Persistent PCS (Group 1), Patients without PCS (Group 2) and Nonconcussed Subjects (Group 3). SD are presented within brackets.

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>27.2 (10.2)</td>
<td>27.4 (10.1)</td>
<td>28.1 (9.6)</td>
</tr>
<tr>
<td>Time</td>
<td>22.6 (7.6)</td>
<td>22.9 (7.5)</td>
<td>22.9 (7.5)</td>
</tr>
<tr>
<td>Educ</td>
<td>4.6 (1.3)</td>
<td>5.1 (1.2)</td>
<td>4.9 (1.0)</td>
</tr>
<tr>
<td>IQ</td>
<td>105.3 (11.3)</td>
<td>110.1 (8.2)</td>
<td>107.1 (15.3)</td>
</tr>
</tbody>
</table>

We measured cortisol levels in saliva because saliva can be collected repeatedly and without stress. In addition, cortisol concentrations in saliva are highly correlated with the plasma “free fraction,” which is considered to be the biologically active hormone, and are independent of the flow of saliva (Vining & McGinley, 1986).

SUBJECTS AND METHODS

Subjects

Patients (n = 11) with persistent PCS were selected from a survey population of patients with mild head injury, who had been admitted to the Emergency department of the University Hospital Maastricht between 1987 and 1990. The criteria for inclusion in the study included a posttraumatic interval of between 12 and 34 months (median 21 months), a posttraumatic amnesia not exceeding 60 minutes, a period of unconsciousness of less than 15 minutes, a Glasgow Coma Score of 15 on admission, and no serious traumatic physical complication (including the absence of orthopedic injury). Patients who had been drinking alcohol before the trauma or who had a skull fracture were also excluded. One subject was involved in a litigation-compensation affair; none had a history of a neuropsychiatric disorder. No patient was under medication at the time of testing and none suffered from any severe perceptual (visual or auditory) or motor problem that would prevent them from undertaking the reaction task. The MHI patients without PCS (n = 11) were selected from the same population on the basis of matching criteria with the patients with persistent PCS. The uninjured subjects (n = 11) were selected from a pool of nonconcussed healthy volunteers. Both the patients without PCS and the healthy volunteers were individually matched with the patients with PCS for age (+/- 6 years), sex, education (+/- 1 level; Verhage, 1964), and IQ (+/- 8 IQ points). Levels of IQ were measured with the Groninger Intelligence Scale (Luteijn and Van der Ploeg, 1983). Each group consisted of six males and five females. The mean age, time elapsed after trauma, and educational level are presented in Table 1. All subjects gave their informed consent.

Procedure

Saliva samples for the determination of cortisol were taken immediately before and after a cognitive test (vigilance task). Patients were tested only in the afternoon or early evening as cortisol levels in this period are low and stable relative to the diurnal pattern. Patients relaxed in a quiet environment for 15 minutes before the start of the vigilance task. After blood had been collected for the second time, a coping
questionnaire was completed (see below). This study was the first part of a larger neuropsychological project involving MHI patients. Details of the neuropsychological results of the study are being analyzed.

Postconcussive Symptoms

A checklist of postconcussive symptoms was completed, which included items of headache, nausea, dizziness, difficulties with concentration and memory, fatigue, and sleep disturbances. As these symptoms also occur in healthy individuals (Dikmen, McLean & Temkin, 1986), the symptoms were scored for the absolute or increased appearance after the injury in comparison with the pretraumatic condition. Six patients with persistent PCS (N = 11) complained of 3 symptoms or more, and five patients complained of 2 symptoms. By definition, patients without PCS did not report any symptom.

Vigilance Task

In the computerized sustained attention task, a small spot, which was moving in a stepwise fashion along an imaginative circle (diameter 11 cm), was presented on a monitor screen of 20 × 28 cm (Vienna test system, Schuhfried GmbH, Austria). The spot made 50 small regular steps (7.2°) per round, randomly interspersed with a double step (5 per round). The total time per step was 1 second. The subjects were requested to press a button when a double step occurred (= the signal). A hundred signals occurred within the total testing time of 12.5 minutes. Each session was preceded by a practice session of 2.5 minutes. A vigilance parameter was calculated as the difference between the mean reaction times of the first and second half of the test (RT2-RT1).

Utrecht Coping List

The Utrecht Coping List is a 47-item questionnaire describing styles of coping that have been derived by factor analysis (Schreurs, Van de Willige, Tellegen and Brosschot, 1987). Sum scores are calculated for each of the seven subscales. Subscale 1 (7 items) “active problem solving” describes a direct and rational approach towards problem situations. Subscale 2 (8 items) “palliative response” include items of seeking distraction, trying to feel better by smoking, drinking, or relaxing. Subscale 3 (8 items) “avoidance and passive expectancy” involves items of problem avoidance or awaiting the consequences. Subscale 4 (6 items) “seeking social support” includes items of seeking help from others. Subscale 5 (7 items) “depressive reaction” involves items of being overwhelmed by the problem and of being pessimistic about the outcome. Subscale 6 (3 items) “expression of emotion and anger” defines an expressive emotional reaction to problems. Finally, subscale 7 (5 items) “comforting cognitions” includes items of considering the problem in a relative way, of self-encouragement, and of a positive reframing of the situation.

Salivary Cortisol

Saliva was collected by holding an absorbent cotton roll in the mouth for 1–2 minutes. The roll was then placed in a capped plastic vial (“Salivette,” Sarstedt B.V.) and stored at −20° C until analysis. Experiments in our laboratory have demonstrated
that cortisol levels in saliva collected with Salivette cotton rolls do not differ from levels in matched samples collected in plain tubes (Salon, personal communication). Salivary cortisol was determined in duplicate by direct radioimmunoassay (Ansseau, Salon, Doumont, Cerfontaine, Legros, Sodoyez & Demey-Ponsart, 1984), using 125I-cortisol (Farmos diagnostica, Finland) and anticortisol antiserum (made against the 3-CMO-BSA conjugate). (Dr. J. Salon of the Steroid Laboratory, University Hospital, Liege, Belgium.) Salivary cortisol was measured from nonextracted saliva (25 microliters), as we have found a very high correlation between extracted (with ethylacetate) and nonextracted saliva ($r = .99$, $n = 20, p < .001$), confirming the absence of corticosteroid-binding protein in saliva. The lower detection limit of the assay was .69 nmol/l, with an intra-assay coefficient of variation of 4.4%. All samples were analyzed in the same assay.

**Statistical Analysis**

Difference scores of “after” minus “before” cortisol values were calculated and used for analysis (“cortisol response”). An analysis of variance was used to assess differences between the three groups. Duncan’s multiple range test was used to evaluate significant main effects (SAS, 1985). As results for the cortisol response did not approximate a Gaussian distribution, ranks over all observations were calculated and used for statistical analysis (Conover & Iman, 1981). Probabilities greater than .05 were considered nonsignificant.

**RESULTS**

Results on the coping styles are presented in Table 2. ANOVA revealed significant “group” effects for the coping styles “active problem solving” and “depressive reaction.” Patients with PCS had lower scores on the “active problem solving” scale than asymptomatic patients. In addition, the symptomatic patients displayed a greater depressive reaction toward problems than the subjects of the two control groups (see Table 2).
TABLE 3
Results of the Vigilance Task are presented together with the Cortisol Values before and after this Task (Means ± SD; Salivary Cortisol: nmol/L)

<table>
<thead>
<tr>
<th>Test of Cortisol Response</th>
<th>MHI Patients with PCS</th>
<th>MHI Patients without PCS</th>
<th>Healthy Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>cortisol before</td>
<td>2.29 (0.98)</td>
<td>1.76 (1.27)</td>
<td>1.96 (0.82)</td>
</tr>
<tr>
<td>cortisol after</td>
<td>2.36 (1.56)</td>
<td>1.38 (0.86)</td>
<td>1.65 (0.71)</td>
</tr>
<tr>
<td>VIGILANCE TASK (time in seconds)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>first half (RT)</td>
<td>56 (0.11)</td>
<td>50 (0.06)</td>
<td>51 (0.07)</td>
</tr>
<tr>
<td>second half (RT)</td>
<td>60 (0.13)</td>
<td>52 (0.08)</td>
<td>51 (0.07)</td>
</tr>
</tbody>
</table>

There was no significant group effect for the cortisol parameter (ANOVA; Table 3). Scores for the vigilance task were analyzed with an ANOVA, with the cortisol parameter as covariate. There was an overall significant test effect [F(1, 27) = 3.92, p < .01], with a significant group*cortisol interaction term [F(1, 26) = 3.40, p < .05], a significant main effect for "group" [F(1, 32) = 3.45, p < .05], and a significant "cortisol" covariate term [F(1, 32) = 4.47, p < .05]. Duncan’s multiple range test of the main “group” effect indicated that the PCS patient group performed the vigilance task significantly less well than the nonconcussed control subjects but not worse than the asymptomatic patient group (Table 3). The covariate term of the cortisol parameter indicated that the decrements in the vigilance task were positively correlated with higher cortisol responses during the task (R = .54; p < .05). The group*cortisol interaction term was evaluated by further subgroup analysis. Comparison of the Spearman correlation coefficients between the individual cortisol response and the scores on the vigilance task within each separate group revealed a stronger correlation in the asymptomatic patient group (R = .79) than in the PCS group (R = .10) and the nonconcussed group (R = .34). Pairwise comparisons between groups indicated that performance in the vigilance task was significantly more related to the cortisol response in the asymptomatic patient group than in the PCS group [F(1, 17) = 4.67; p < .05] and in the nonconcussed group [F(1, 17) = 3.89; p < .05].

DISCUSSION

According to the coping hypothesis (Van Zomeren & Van den Burg, 1985; Hinkeldey and Corrigan, 1990), postconcussive complaints may result from the chronic effort patients make to compensate for their cognitive deficits, leading to a chronic stress reaction. This notion is supported by data reported by Bornstein, Miller and Van Schoor (1989), who found a positive relationship between emotional disturbance and cognitive deficits in patients with minor head injury. To try to understand more about factors determining patient’s residual complaints and long-term adjustment to disability, Hinkeldey and Corrigan (1990) examined the coping strategies used by head-injured subjects to deal with their difficulties. Severely head-injured patients reported a significantly greater use of avoidance and affective regulation as a method of coping, and a decreased use of logical analysis and information seeking strategies. Further evidence for the coping hypothesis was provided by our results indicating that symptomatic patients demonstrated a decreased use of the coping style “active problem solving” and reacted more with a depressive attitude toward problems. Thus,
the stress tolerance of MHI patients with PCS may be decreased, and frustration readily develops when previously mastered activities at home or work prove challenging if not impossible. Difficulties in cognitive functioning may reduce the effectiveness in coping with stress.

Posttraumatic adaptive skills are viewed as the net effect of premorbid adjustment, response to cognitive impairment, patient's own standard and expectancy, and level of perceived stress (Long & Webb, 1983; Van Zomeren & Van den Burg, 1985). These adaptive skills have to be considered in the perspective of environmental demands. The development of effective techniques for stress management, such as the provision of information and assistance in developing more adaptive coping strategies, could be an important component of treatment programs for MHI patients.

With respect to cortisol reactivity during the cognitive task, we did not find that symptomatic MHI patients had a significantly increased cortisol response during a vigilance task in comparison with MHI patients without PCS and healthy subjects. The lack of an increased cortisol response in MHI patients with PCS does not support the coping hypothesis. It is possible that, given the evidence of a decreased coping ability in the PCS group, these patients may experience a chronic stress reaction that is rather insensitive to the superimposed stressor in the present model. Factors that may be related to the outcome of the present study include the relatively long time after the injury, and the mild nature of the head injury. Given the nonsignificant trend of a slightly increased cortisol response in the PCS group (Table 3), it is possible that the same experiment with more severely injured patients in a subacute stage after injury would reveal an increased cortisol response. Fatigue can be discarded as a biasing factor in a short-lasting, low-event rate vigilance task. Moreover, the task was preceded by a rest period of about 15 minutes.

To date, little attention has been paid to individual differences in the response of the psychoendocrine system in relation to performance in cognitive tasks. Bohnen et al. (1990) reported that an individually increased cortisol reactivity during mental stress was negatively related to attentional performance. The cortisol response identified those individuals who were more vulnerable to the negative effects of stress. We now present similar evidence that performance in a cognitive task decreases with increased cortisol reactivity. Further subgroup analyses indicated that this effect was significantly greater in the group of apparently recovered MHI patients than in nonconcussed subjects and symptomatic MHI patients. Similar results were reported by Ewing, McCarthy, Gronwall and Wrightson (1980) that apparently recovered MHI patients manifest a greater CNS vulnerability to stressors than nonconcussed controls. It is possible that these apparently recovered patients, because of their better coping ability, compensate for their latent cognitive deficits when the stress is not too high. Whether or not such a hypothesized compensatory effort is related to an increased controlled processing of information (Shiffrin & Schneider, 1977) could be a subject of further study. Although the performance of the PCS group in the vigilance task was significantly worse than that of the two control groups, this performance decrement was not related to the cortisol response. It is possible that the cognitive dysfunction in the PCS group reflects some form of structural brain damage (Van Zomeren & Van den Burg, 1985) or has other origins, such as depression. It can be summarized that patients with persisting PCS after MHI make less use of effective coping mechanisms. In addition, performance in a vigilance task appears to be related primarily to cortisol reactivity during this task, especially in apparently recovered patients. Although we found no direct evidence for an increased cortisol response in the symptomatic patient group, further research is needed to address the complex issue of mutual effects of structural brain damage, stress susceptibility,
and coping ability in MHI patients. Clarification of the relationships between post-traumatic brain dysfunction, cognitive functioning, and objective assessment of the stress response will contribute to a further understanding of the persistence of post-concussive sequelae after a mild head injury.

REFERENCES


