

Whiplash Injury and Mild Traumatic Brain Injury: Differential Effects on Cognitive Functioning?

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Abstract

With regard to whiplash injury (WI) patients, some studies documented mild attention problems and a reduced speed of information processing. Most patients showed problems with sustained and/or divided attention. However, some patients had also problems with focused and alternating attention. Regarding memory, some studies detected mild (auditory-verbal and/or visuospatial) memory difficulties. Visuospatial and executive functions appeared mostly preserved. In mild traumatic brain injury (MTBI) patients, mild impairments in speed of information processing, (sustained, divided, focused and/or alternating) attention and (auditory-verbal and/or visuospatial) memory have been found. Furthermore, mild deficits could also be seen on tests measuring executive functions whereas visuospatial functioning seemed to be preserved. Until today, only two studies were devoted to evaluate possible differences in cognitive functioning between WI and MTBI patients. In these studies, both patient groups did not differ significantly with regard to measurements of attention, memory, and visuospatial and executive functions. Therefore, these authors conclude that MTBI patients do not perform more poorly on cognitive tests than WI patients, as might be expected from severity of trauma.

Introduction

A whiplash injury (WI) can be described as a neck injury due to a sudden, forceful and rapid back-and-forth movement of the neck. It occurs most often during a rear-end vehicle accident but the injury can also result from a sport accident. So, WI patients show a non-contact trauma that does not result in loss of consciousness or a period of post-traumatic amnesia (PTA) which is characterized by confusion and disorientation [1,2].

Mild traumatic brain injury (MTBI) means a mild injury to the head resulting from a blunt trauma and/or acceleration and deceleration forces in the brain. A MTBI can occur most often after a fall, a car crash or a sport accident when the skull is struck by a heavy object. MTBI patients show a period of unconsciousness of less than 15 min and a period of PTA of less than 1 h [3,4].

It is commonly accepted that WI and MTBI can lead to long-lasting cognitive problems. Some authors assume that the post-concussion syndrome (PCS) and the post-whiplash syndrome (PWS) list similar cognitive symptoms [5,6]. Patients with a PCS or PWS show subjective (cognitive, emotional and/or somatic) complaints more than six months post-injury. With regard to cognitive functioning, WI and MTBI patients often complain of poor attention and memory [7]. Several studies have looked for objective findings concerning cognitive dysfunctions after WI [1,2,8-15] and MTBI [16-23] and have found the presence of only mild cognitive deficits, if any, in both patient groups, mainly in the domain of attention, information processing and memory.

Cognitive Problems after Whiplash Injury

With regard to WI patients, most studies documented mild attention problems and a reduced speed of information processing [1,2,8-10,12,14], while in some studies these problems were not found [11,24]. In the majority of studies which could detect attention deficits after WI, most patients showed problems with sustained and/or divided attention. Besides this, some patients had also problems with focused attention (a reduced inhibition of distraction and/or interference) and/or alternating attention (a disturbed conceptual switching). Regarding memory, some authors [11,24] found no memory problems in WI patients. However, in other studies [1,9,25] mild memory difficulties were detected among

WI patients. Most of these patients showed problems with auditory-verbal and/or visuospatial memory and within these memory domains mostly problems with the storage of new information into memory and/or the recall of recently learned information from memory. In contrast, none of the patients showed problems with the recognition of recently stored information from memory. Visuospatial functions [1,11,24] (i.e., visuospatial judgement, visuospatial perception and visuospatial construction) and executive functions [11,24] (i.e., verbal fluency, planning and problem solving and abstract/conceptual reasoning) appeared preserved in WI patients.

In a recent study carried out by Beeckmans et al. [1], global cognitive functioning was investigated in a group of patients with a PWS. The WI group, as compared to a matched control group of healthy controls (HC), was found to be significantly more deficient in speed of performance during sustained and divided attention, focused attention, alternating attention, the storage of new auditory-verbal unrelated information into memory, the long-term delayed recall of stored auditory-verbal related information from memory, abstract/conceptual reasoning and the accuracy of performance during planning and problem solving. No differences could be found between both groups concerning visuospatial memory, visuospatial abilities and verbal fluency. These findings are consistent with findings from previous studies. However, in contrast to other studies [8-10,12,14], the WI patients showed no significantly reduced speed of information processing as was assessed with the Paced Auditory Serial Addition Test (PASAT). The results with regard to executive functioning (i.e.,

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abstract/conceptual reasoning and planning and problem solving) in WI patients are also not in line with other studies [11,24] which found no executive deficits in this patient group. A possible explanation for

this contradictory finding is that only a few studies have yet evaluated executive functions and mostly not extensive. The results of this study are presented in Table 1.

| | WI (N=61) | MTBI (N=57) | HC (N=30) | ANOVA/ KW p-value | Post-hoc p-value |
|---|----------------|----------------|----------------|-------------------------|--|
| Attention | | | | | |
| Bourdon-Wiersma Test (evaluation of sustained attention) | | | | | |
| Mean rule time (s) | 14.0 ± 4.2 (*) | 13.3 ± 3.9 (*) | 11.6 ± 3.2 (*) | <0.001 | WI vs. HC: <0.001 MTBI vs. HC: <0.001 |
| Total omissions | 13 ± 19 (*) | 11 ± 12 (*) | 8 ± 13 (*) | NS | - |
| D-2 Concentration Endurance Test (evaluation of divided attention) | | | | | |
| Total raw score | 405 ± 99 | 439 ± 87 | 512 ± 78 | <0.001 | WI vs. HC: <0.001 MTBI vs. HC: <0.001 |
| Total errors (omissions and additions) | 11 ± 17 (*) | 10 ± 13 (*) | 9 ± 14 (*) | NS | - |
| Stroop (Color/word Interference) Test (evaluation of focused attention) | | | | | |
| Interference score (s) | 45 ± 27 | 34 ± 14 | 27 ± 9 | <0.001 | WI vs. HC: <0.001 MTBI vs. HC: <0.001 |
| Trail Making Test (evaluation of alternating attention) | | | | | |
| Time part B (s) | 87 ± 37 (*) | 81 ± 26 (*) | 64 ± 21 (*) | <0.001 | WI vs. HC: <0.001 MTBI vs. HC: <0.001 |
| Paced Auditory Serial Addition Test (evaluation of speed of information processing) | | | | | |
| Total correct answers | 28 ± 8 | 30 ± 9 | 34 ± 7 | NS | - |
| Memory | | | | | |
| Rey Auditory-verbal Learning Test (evaluation of auditory-verbal memory for unrelated information) | | | | | |
| Total immediate recall over 5 trials | 54 ± 8 | 54 ± 8 | 62 ± 7 | <0.001 | WI vs. HC: <0.001 MTBI vs. HC: <0.001 |
| Long-term delayed recall | 12 ± 4 (*) | 11 ± 4 (*) | 14 ± 3 (*) | 0.001 | MTBI vs. HC: <0.001 |
| Long-term delayed recognition | 15 ± 1 (*) | 14 ± 1 (*) | 15 ± 1 (*) | NS | - |
| Coetsier Story Recall Test (evaluation of auditory-verbal memory for related information) | | | | | |
| Immediate recall | 66 ± 19 (*) | 69 ± 16 (*) | 73 ± 23 (*) | NS | - |
| Long-term delayed recall | 58 ± 14 | 61 ± 15 | 72 ± 14 | <0.001 | WI vs. HC: 0.001 MTBI vs. HC: <0.001 |
| Rey Visual Design Learning Test (evaluation of visuospatial memory for unrelated information) | | | | | |
| Total immediate recall (over 5 trials) | 50 ± 10 | 49 ± 9 | 55 ± 6 | NS | - |
| Long-term delayed recall | 13 ± 4 (*) | 13 ± 4 (*) | 13 ± 2 (*) | NS | - |
| Long-term delayed recognition | 15 ± 1 (*) | 14 ± 1 (*) | 15 ± 0 (*) | NS | - |
| Rey Complex Figure Test (evaluation of visuospatial memory for related information) | | | | | |
| Immediate recall | 24 ± 5 | 25 ± 6 | 24 ± 4 | NS | - |
| Long-term delayed recall | 21 ± 4 | 23 ± 6 | 23 ± 4 | NS | - |
| Visuospatial functions | | | | | |
| Hooper Visual Organization Test (evaluation of visuospatial perception) | | | | | |
| Total correct | 26 ± 2 | 25 ± 3 | 25 ± 2 | NS | - |
| Judgement of Line Orientation Test (evaluation of visuospatial judgement) | | | | | |
| Total correct | 26 ± 3 | 27 ± 2 | 27 ± 2 | NS | - |
| Executive functions | | | | | |
| Controlled Oral Word Association Test (evaluation of verbal fluency) | | | | | |
| Total words generated | 33 ± 9 | 30 ± 8 | 39 ± 10 | <0.001 | MTBI vs. HC: <0.001 |
| Short Category Test (evaluation of abstract/conceptual reasoning) | | | | | |
| Age-corrected T-score | 56 ± 8 (*) | 52 ± 15 (*) | 64 ± 10 (*) | 0.001 | WI vs. HC: <0.001 MTBI vs. HC: 0.002 |
| Chapuis Maze Test (evaluation of planning and problem solving) | | | | | |
| Total time (s) | 210 ± 64 (*) | 212 ± 94 (*) | 225 ± 158 (*) | NS | - |
| Total errors | 4.5 ± 3.5 (*) | 6.0 ± 4.3 (*) | 2.3 ± 3.8 (*) | <0.001 | WI vs. HC: 0.001 MTBI vs. HC: <0.001 |

Table 1: Overview of cognitive functioning in whiplash injury patients (WI) compared to patients suffering from a mild traumatic brain injury (MTBI) and healthy controls (HC).

Data are presented as mean ± standard deviation (SD) or as median ± interquartile range (IQR) where specified with (*), at a p-value of 0.002 Bonferonni corrected. KW: Kruskal-Wallis test; NS: Not Significant [1]

Most imaging (CT and/or MRI) studies [14,26,27] carried out with WI patients failed to find evidence of the presence of structural brain pathology. According to Antepohl et al. [10], the presence of headache and neck pain is likely to be responsible for the cognitive problems seen in chronically symptomatic WI patients. Furthermore, psychiatric morbidity, impaired psychological functioning (i.e., depression, anxiety, distress, etc.), as a reaction to the injury and its consequences in the family, social and professional context, fatigue, a reduced health-related quality of life and the use of psycho-active drugs might also be the cause of reduced cognitive functioning [2,7,24,28,29]. Malingering is also thought to contribute to post-whiplash symptoms [30]. However, it must be said that patients with psychiatric morbidity, use of psychotropic medication or malingering are excluded in most studies investigating cognitive disturbances after WI.

Cognitive Problems after Mild Traumatic Brain Injury

In MTBI patients, mild impairments in speed of information processing, (sustained, divided, focused and/or alternating) attention and (auditory-verbal and/or visuospatial) memory have been found [1,13,16,17,19,20-23]. With regard to memory, most patients displayed deficits concerning the storage of new information into memory and/or the reproduction of recently learned information from memory. Besides this, some patients showed also problems with the recognition of recently stored information from memory. Furthermore, mild deficits could also be seen on tests measuring executive functions whereas in most studies visuospatial functioning seemed to be preserved [1,16-18,29,30]. The above described findings with regard to cognitive functioning after MTBI were also presented in a meta-analysis of Belanger et al. [3] and Frencham et al. [4].

In the study of Beeckmans et al. [1], global cognitive functioning was not only explored in a group of patients with a PWS but also in a group of patients with a PCS. The MTBI group, as compared to a matched control group of HC, was found to be significantly more deficient in speed of performance during sustained and divided attention, focused attention, alternating attention, the storage of new auditory-verbal unrelated information into memory, the long-term delayed recall of stored auditory-verbal unrelated and related information from memory, verbal fluency, abstract/conceptual reasoning and the accuracy of performance during planning and problem solving. Both groups displayed no differences for visuospatial memory and visuospatial abilities. The outcome of the study is compatible with findings from other studies. However, in contrast to previous studies [1,13,16,17,19,20-23], the MTBI patients showed no significantly reduced speed of information processing as was evaluated with the PASAT. An overview of the results of this study can be seen in Table 1.

Concerning the cause of these mild cognitive problems, there is evidence from recent MRI studies showing the presence of a mild cerebral pathology in most patients with a MTBI. According to some authors [22,30-32], the majority of these lesions are mainly focal because they are localized in the white matter of the frontal and temporal (limbic) lobes.

Is there a difference in cognitive functioning between whiplash injury patients and mild traumatic brain injury patients?

Taylor et al. [6] assumed that if cerebral changes play a role in the cognitive consequences of WI or MTBI, the severity of trauma should predict the outcome. As MTBI patients suffer loss of consciousness and PTA immediately following a trauma, they expected worse test performances on tests assessing attention in this group rather than in a

group of WI patients with no loss of consciousness or PTA. However, no significant differences in attention functioning between 15 WI patients and 10 MTBI patients emerged in their study. It should be noted that 13 out of the 15 included WI patients underwent a CT of the brain and that the result was normal. However, it is a disadvantage that none of the WI patients underwent an MRI of the brain. So, the authors conclude that attention deficits seen in WI patients might be due to neck pain while in MTBI patients these attention problems might be the consequence of a mild cerebral pathology.

Beeckmans et al. [1] have conducted a study to investigate differences in a variety of cognitive functions (i.e., attention, information processing, memory, visuospatial and executive functions) between a group of 61 WI patients and a group of 57 MTBI patients. The patients were examined with an extensive neuropsychological test battery (Table 1). In both patient groups, participants showed persistent cognitive symptoms (more than 6 months post-injury). All patients underwent structural brain imaging (CT or MRI). On the basis of a CT (n=23) or an MRI (n=38), the WI patients showed no lesions in the brain. The authors found evidence that the WI and MTBI group did not differ significantly on the 23 test variables which were investigated (Table 1). Therefore, the authors state that there is no strong statistical evidence to reject the hypothesis which suggests that long-lasting cognitive deficits seen in patients with a WI correspond to those noted in patients with a MTBI. Indeed, it was noticed that their WI and MTBI patients were similar in cognitive functioning. This statement deserves careful consideration because severity of trauma did not predict the neuropsychological outcome in their study. Because the authors have no evidence to assume cerebral changes in their WI patients, they attribute the cognitive problems in this group mainly to the effect of neck pain on cognitive functioning. In contrast, the cognitive deficits seen in patients with a MTBI are principally determined by a cerebral pathology as all patients suffered loss of consciousness and PTA immediately after the injury. So, their findings agree with the results of the study carried out by Taylor et al. [6] which was only devoted to attention functioning in both groups of interest. In conclusion the authors state that pain, as a result of injury to the neck, may have an equal influence on cognitive performances in WI patients as may have a direct cerebral impact in MTBI patients. This finding may explain why MTBI patients do not perform more poorly than WI patients, as might be expected from severity of trauma (Table 1).

Conclusion

A lot of studies have assessed cognitive functioning after WI or MTBI. Based on the results of these studies, clinicians have now a comprehensive insight in the cognitive profile of WI and MTBI patients. However, more studies are needed to investigate differences or similarities in global cognitive functioning between WI and MTBI patients. Until today, only two studies [1,6] have explored this subject.

Besides neck pain (in WI patients) and a mild cerebral pathology (based on results from MRI in MTBI patients), it would also be interesting to look for other somatic causes (i.e., headache, fatigue, visual problems and insomnia) and also psychological causes (i.e., depression, anxiety, tension and distress), physiopathological causes (i.e., changes in cerebral blood flow, cerebral metabolic dysfunction, inadequate cerebral oxygenation in the brain, etc.) and neurobiochemical causes (i.e., alterations in neurotransmitter synthesis, release or re-uptake mechanisms, ...in the brain) which could explain the cognitive deficits in WI and MTBI patients.

Besides cognitive problems, a lot of patients with WI or MTBI complain also about mild language problems such as word-finding difficulties.

Therefore, we advise that future studies should also add questionnaires, scales and other measures to evaluate somatic, psychological, physiopathological and neurobiochemical variables and tests to evaluate word-finding to the methodology. This global assessment approach is also necessary to help clinicians in their broader (differential) diagnostic and therapeutic activities.

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