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The Cognitive and Behavioural Impact of the Development of Post-Traumatic Stress Disorder (PTSD) Associated with Traumatic Brain Injury (TBI): A Systematic Review

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Abstract

Introduction: Mild Traumatic Brain Injury patients (MTBI) develop Post-Traumatic Stress Disorder (PTSD) symptoms following their stressful event. Many patients of the civilian population who underwent mTBI might develop cognitive and behavioural changes alongside PTSD symptoms. The aim of this systematic review was to search for all the existing literature that studied the cognitive and behavioural impact of the development of PTSD associated with mTBI in the civilian population.

Method: All articles were selected from the PubMed database and were reviewed for potential inclusion in March 2022. These particles underwent screening for certain inclusion\exclusion criteria. We identified 6 articles that investigated the cognitive decline after the development of PTSD associated with mTBI.

Results: The major findings where the severity of PTSD symptoms depends on various factors, namely the correlation of GOS-E Glasgow Scale-Extended Outcome scores, worsening the Symptoms of PTSD, the cognitive changes after the development of PTSD associated with mTBI, and the behavioural changes after the development of PTSD associated with mTBI. The main finding revealed that there is a cognitive and behavioural impact such as verbal long-term memory impairment, attention deficit, PTSD, depression, anxiety, and apathy, which also impacted civilian patients' quality of life. We discussed various research and systematic reviews, which included the neuropsychological and functional outcomes, the severity of symptoms of PTSD, GOS-E scores, the severity of the impact, the post-traumatic period, as well as the quality of life following the diagnosis of PTSD.

Conclusion: We identified certain limitations to the subject at hand; there is an undeniable need for further research on the impact of PTSD on mTBI patients, as well as the cognitive and behavioural impact following such trauma on the civilian population. We recommend expanding the studies in this area to improve the clinical outcomes and treatment plans, which improve the patient's quality of life.

Keywords: Traumatic brain injury; Post-traumatic stress disorder; Memory; Attention; Anxiety; Depression

Introduction

Traumatic Brain Injury (TBI) is defined as "an alteration in brain function, or other evidence of brain pathology, caused by an external force" [8]. Mild Traumatic Brain Injuries (mTBI) is one of the most common types of TBI and is defined as "traumatically induced disruption of brain functions" [11]. There are certain criteria before patients are diagnosed with mTBI, including those of loss of consciousness, any loss of memory pre- or post-traumatic event, any changes in the mental status at the time of the incident, and having a neurological deficit. The criteria also exclude any loss of consciousness longer than 30 minutes, after 30 minutes the Glasgow Outcome Scale-Extended (GOS-E) score of 13 to 15, as well as post-traumatic amnesia less than 24 hours [11]. Post-traumatic stress disorder (PTSD), "is the development of characteristic symptoms following exposure to one or more traumatic events" [1]. In addition, there is an annual incidence of TBI in 69 million patients worldwide, with the greatest estimated incidence in North America and Europe due to those regions having higher-quality data while Africa marked the least amount of incidence. Meanwhile, road traffic accidents account for the highest leading cause of TBI in Africa and Southwest Asia [5]. There is an existing study that estimated the prevalence of PTSD to be around 8% in the general US population. The comorbidity of both to occur is common within the general population, and it might be hard to determine the association of PTSD after TBI, yet it is estimated to

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range from 1 to 50 % [15]. A study "reported PTSD in 14.1% of TBI patients, which was 5.8 times the relative risk observed in the general community population". Although it has been previously argued that PTSD and TBI are not associated with one another, taking into account the loss of consciousness and the common memory loss acts as preventive factors against developing PTSD. Various studies observed and reported that even in the presence of such symptoms PTSD is associated with TBI patients [14].

Patients experiencing TBI often undergo some sort of psychological trauma whether it was following road traffic accidents, military combat, or even undergoing personal violence. When TBI is associated with psychological trauma it may lead to the development of PTSD [16].

Post-traumatic stress disorder is a mental health disorder with a lifetime prevalence of 3.9% [9]. In the civilian population, the relative frequency of PTSD following TBI after 12 months was 18.6% in contrast to 11% in 2 years [8]. Well-controlled studies indicate that the incidence of PTSD after mTBI is between 17 and 33% [3].

There are two existing systematic reviews that investigate PTSD following TBI. Research done by Loignon et al. aimed to investigate the probability of developing PTSD in TBI and non-TBI populations, as well as comparing the risk between the military\veteran and the civilian population. It reported that "TBI diagnosis and military setting represent greater risks for PTSD. The dual diagnosis of TBI and PTSD requires interdisciplinary collaboration, as physical and psychological traumas are closely intertwined" [10]. It was concluded that civilians and military personnel who were diagnosed with TBI have a higher risk of developing PTSD.

Furthermore, another research done by Iljazi et al. was "to estimate the relative frequency and relative risk of PTSD attributed to TBI". They concluded that in clinic-based civilian populations, TBI is a risk factor for developing PTSD. There is inadequate data to determine the relative incidence or risk of PTSD in those who have experienced mild to severe TBI [8].

Neurophysiological\neuropsychiatric disorders are complex yet poorly defined neurobiological bases. Neuropsychological disorders have a major impact on brain functions including those of cognition and behavioural [2].

Some symptoms are associated with PTSD such as intrusive recollections, avoidance of stimuli related to traumatic material, numbing of emotional responsiveness and hyperarousal symptoms [15]. It is reported that 80% of patients diagnosed with co-morbid psychiatric disorders alongside PTSD, substance abuse, depression, and anxiety are the most commonly reported disorders [15]. There is a strong association between PTSD and suicidal ideation and suicidal attempts. Whereas, TBI symptoms are strongly associated with the severity of the injuries and the time post-injury [15]. In the cases of mild TBI, most patients are diagnosed with Post Concussive Symptoms (PCS) within the first weeks to months from their injuries. On the other hand, severe TBI patients are diagnosed with various levels of disruption of consciousness immediately after their injury alongside physical, neurological or cognitive symptoms that last months after their injury. TBI is associated with behavioural and neuropsychiatric symptoms such as aggression, depression, suicidality, and anxiety disorders [15].

Some studies discuss the influence of PTSD in association with TBI and their influence on one another. Their influence on one another can produce symptoms including both cognitive and behavioural symptoms. Patients dealing with PTSD in association with TBI, experience cognitive impairments including difficulty in concentrating, slow thinking, and memory impairment, having to reread, failure\learning people's names, daydreaming instead of listening, not being attentive to others, difficulty making decisions, being easily distracted, forgetting purchases, losing the train of thought, forgetting appointments. Behavioural changes are manifested as sleep distribution, irritability, apathetic symptoms such as losing interest, problem initiating an activity, psychomotor slowness, disinhibition symptoms such as being easily irritable, laughing and crying easily, interrupting others, dysexecutive symptoms such as sensible distractors, mixing sequences\actions and remembering too late [12,15]. Dissociative symptoms including those of depersonalisation, derealisation, and dissociative amnesia [3]. And comorbidity such as depression, substance use disorders, pain, and somatic disorders [15].

The most recent systematic reviews focused on the probability of developing PTSD in association with TBI patients with no further discussion on the cognitive and behaviour changes after developing PTSD associated with mTBI. According to two systematic reviews done by [8,10]. Patients with TBI are at a high risk of developing PTSD. After reviewing these two studies, we noticed there was no further discussion to cover the risks associated with TBI or mTBI and their association with developing PTSD, which is considered a second limitation. Therefore, this area needs further investigation to expand and demonstrate the cognitive and behavioural impact associated with PTSD after TBI on the civilian population. A third limitation arises based on the recent systematic reviews, there was a focus on the military\veteran population after TBI in association with developing PTSD. There are further elaborations on the military personnel and a limitation when it comes to the civilians experiencing PTSD after the TBI incident. Incidents of PTSD following TBI could have a behavioural impact on the general population. This impact needs elaboration to provide a clear understanding of the quality of life of patients living with TBI in association with PTSD and long-term cognitive and behavioural changes [3]. There are no existing systematic reviews that clarify the impact of PTSD in association with mTBI in the civilian population.

Therefore, the aim of this systematic review was to search for all the existing literature that studied the cognitive and behavioural impact of the development of PTSD associated with mTBI in the civilian population. Furthermore, this review will attempt to determine which cognitive and behavioural changes are most experienced in PTSD associated with TBI patients. This review also will point out any limitations of the existing reviews and provide guidance for further research.

Method

A systematic review of published research articles that focused on the cognitive and behavioural changes in PTSD associated with mTBI patients was carried out. Online articles search of the PubMed database were carried out based on the aim of the present review, the

following keywords were used in: "(Post-Traumatic Stress Disorder or PTSD) and (Traumatic Brain Injury or TBI) and (cognitive impairment or cognitive changes including memory, attention and executive function or behavioural changes including depression, anxiety, and all of their possible combinations)".

All published papers up to March 2022 were searched. The initial search identified 232 titles and abstracts, and then 48 duplicate publications were excluded. The abstracts and complete reports were reviewed to exclude articles according to the following exclusion criteria: (1) reports published only in abstract format, (2) case reports\study, (3) articles written in languages other than English, (4) systematic reviews and studies on children under 18 years old, (5) studies done on military\veteran populations, (6) severe to moderate TBI studies, (7) articles discussing psychiatric disorders related to TBI but not associated with PTSD, (8) articles discussing treatment plans for PTSD associated with TBI, (9) articles discussing the differential diagnosis of PTSD and TBI, (10) articles discussing cognitive\ neurorehabilitation, and (11) studies experimenting on rat models. Based on our exclusion criteria, we excluded 174 publications. A total of 6 articles met our inclusion criteria, those articles had to: have cognitive and behavioural changes, mTBI due to road traffic accidents as well as others, PTSD cases related to TBI incidence, impact and risks of having both morbidities of TBI and PTSD, a mean age above 18, studies that focused mainly on the civilian population, neuropsychological symptoms experienced by mTBI in the general population, and psychological disorders (Figure 1, Table 1 & Table 2). This methodological decision was made to demonstrate the cognitive and behavioural changes acquired in PTSD in association with mTBI in the civilian population, as well as reporting on current studies available that discuss the psychological impact associated with mTBI on our targeted population.

Results

The process of the literature search is illustrated in (Figure 1). In total, 232 studies were reviewed including duplicate articles from the database. After we excluded duplicate articles, 181 full copies were retrieved and evaluated for eligibility. This review identified 6 articles that reported PTSD incidents associated with mTBI and its severity, and cognitive and behavioural changes related to PTSD in association with mTBI. However, upon further review of the full papers, 174 articles did not meet the inclusion criteria as they reported PTSD incidents associated with severe or moderate TBI or non-specific severity in relation to TBI, other articles focused their review on the military\veteran population, and other articles focused on non-cognitive and behavioural changes related to PTSD in association with mTBI. There were 6 articles included in this review. Cognitive tests, behavioural assessments, and their results are summarised in (Table 1 & Table 2).

An in-depth review of the findings of the included articles is provided below. We will focus on PTSD incidents associated with mTBI and the severity of PTSD associated with mTBI, cognitive\ functional changes in patients diagnosed with PTSD associated with mTBI, and behavioural changes in patients diagnosed with PTSD associated with mTBI.

PTSD Incidence and Its Severity Associated With mTBI

Mild traumatic brain injury incidents account for 85% of all brain injuries, yet it is clinically less researched in comparison to moderate to severe TBI. Although mTBI has by far more favourable outcomes than moderate to severe TBI, patients who have experienced mTBI report various neuropsychological changes that vary in severity. In a previous study, patients who suffered mTBI were assessed on the possibility of clinically meeting the criteria for PTSD. Although PTSD is clinically serious, it's not receiving enough clinical care in the diagnosis and patient follow-up of post-mTBI [4]. Of all participants who underwent the PTSD Checklist – Civilian Version (PCL-C), 2 out of 10 participants who have been in a high-risk group reported PTSD symptoms including those of recollection of memories regarding their incident, hyperarousal state, and avoiding their health status. Whereas 60% complained of 1 out 3 symptoms in contrast to 30% who had previous pre-existing psychological comorbidity and were taking psychiatric medications. In the study, it was confirmed that the PCL-C scores were highly indicative of PTSD screening in patients following mTBI [4].

According to Pineau et al., the study assessed four groups of participants using the Structured Clinical Interview for DSM-IV Axis I (SCID), which revealed the diagnosis of PTSD across 4 groups including PTSD, mTBI, mTBI\PTSD, and control group. The proportion of participants suffering from PTSD was specified from moderate to severe. An overall prevalence of PTSD was greater in the PTSD group by 64% more than in the mTBI/PTSD group, which was 17%. Furthermore, severe PTSD was reported in the PTSD group with an average of 32% of participants, while there were zero reports of severity in the mTBI\PTSD group. Around 33% of participants in the mTBI\PTSD were diagnosed with mild to moderate PTSD.

However, participants in the mTBI group showed subclinical symptoms or partial PTSD, with only 4% within the PTSD group. On the other hand, the study revealed that the PTSD group identified with a secondary diagnosis other than PTSD more than the mTBI group. According to another study evaluating the incidence of PTSD among patients who have experienced mTBI in high- and low-risk groups using PCL-C. It was demonstrated that PCL-C scores are useful to confirm PTSD in mTBI-affected patients [4].

Cognitive\Functional Outcomes in Patients Diagnosed With PTSD Associated With mTBI

An existing article by Pineau et al. where the study divided participants into four groups who have been diagnosed with psychological and/or neurological traumas: participants with PTSD, mTBI, double diagnosis of PTSD and mTBI, and a control group. The study collected cognitive and behavioural symptoms experienced in each group using different parameters including the digit symbol test from Wechsler Adult Intelligence Scale, third edition (WAIS-III), Stroop Task, The California Verbal Learning Test, and Second edition (CVLT-II) (Table 1). As well as addressing the severity of PTSD based on the SCID. It was observed that a greater majority of participants suffering from moderate to severe PTSD were within the PTSD group than they were in the mTBI\PTSD group.

The Cognitive Failure Questionnaire (CFQ) was performed in all 4 groups to observe multiple cognitive and behavioural changes across all participants. Significant distractibility was reported greater in the PTSD group than in the mTBI group. Based on the CFQ, 70% of participants within the PTSD group reported being easily

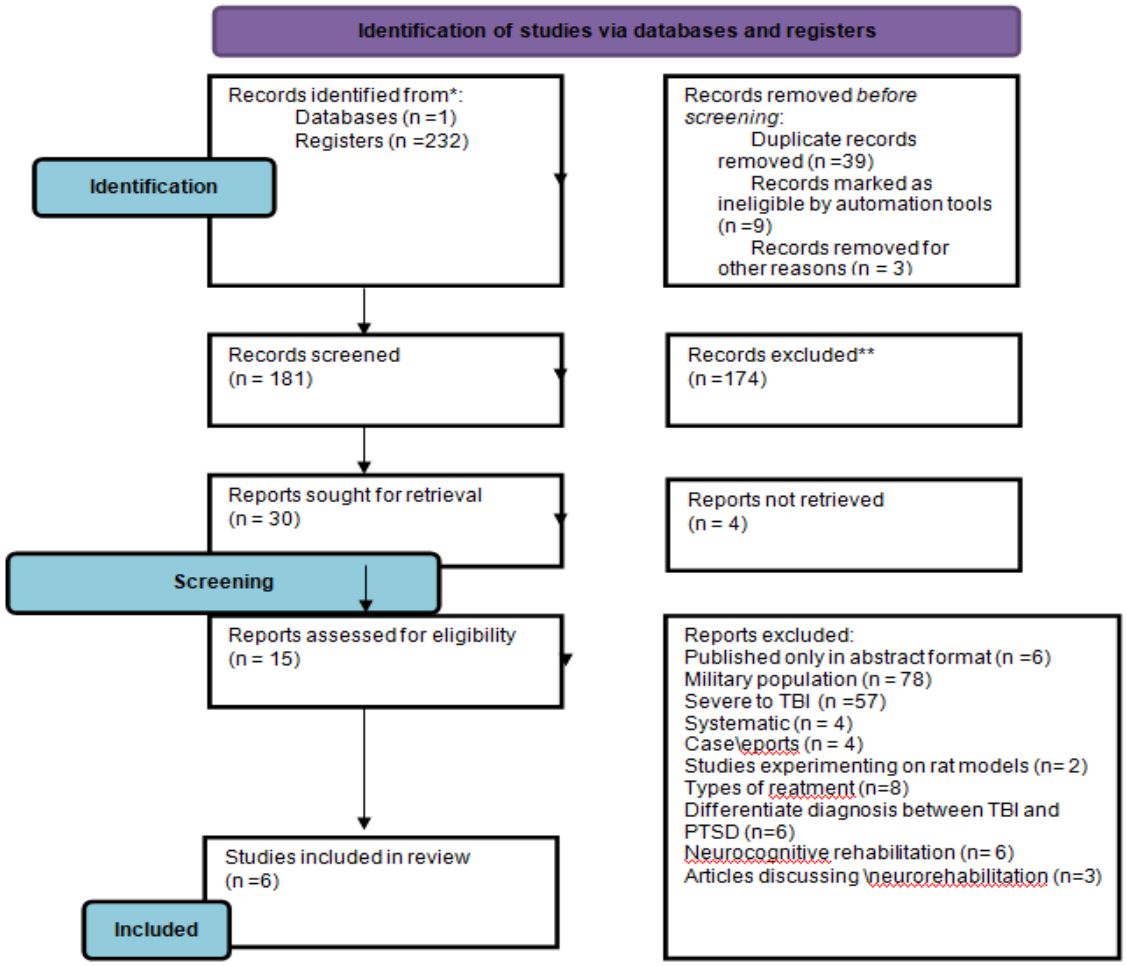

Figure 1: PRISMA flow diagram of the study selection process.

distracted, and not attentive to others, while 83% of participants in the mTBI\PTSD group reported forgetting appointments and difficulty concentrating was reported by 95% of patients in PTSD and mTBI\PTSD group, yet only 63% of the mTBI group reported such symptoms. Upon comparing the clinical groups, it was observed that a significant number of complaints came from the clinical groups rather than the controls [13].

Overall, PTSD group participants showed significant change post-event on all parameters. A neuropsychological battery was used to assess PTSD symptoms associated with mTBI and their impacts either cognitively or behaviourally. Such cognitive assessments were GOS-E, Test Rivermead Post-Concussion Questionnaire-13 (RPQ-13), Trail Making Test Part A&B (TMT), the California Verbal Learning Test (CVLT-II), the Wechsler Adult Intelligence Scale, Fourth Edition, and Processing Speed Index (WAIS-PSI). Different performances of participants were measured after 6 months after experiencing mTBI based on concurrent outcomes measures. A higher frequency of reported PTSD symptoms after 6 months of post-TBI was found in individuals with a GOS-E score of 5, followed by scores of 6 and [7].

For instance, in a study done by Haagsma et al. GOSE scores were also collected to evaluate the functional outcomes in PTSD patients following their mTBI. Another study illustrated a significant association in patients with lower scores in the GOS-E and PTSD, as well as suggesting patients with genetic variation of catechol-o-Methyltransferase (MET) COMT VAL 158 mutation influenced their higher risk of experiencing PTSD associated with mTBI, relating genetic variations as a source of the variable clinical outcomes associated with TBI (Table 1). Patients with COMT VAL 158 mutation and variations have a higher possibility of developing PTSD associated with mTBI [7].

On the other hand, another scale that was used to evaluate the functional outcomes in such patients was the Perceived Quality of Life Scale (PQoL) consisting of a 36-item questionnaire which covers 8 domains of health status: Physical Functioning (PF), Role Limitations Related to Physical Health Problems (RP), Bodily Pain (BP), Heneral Health Perception (GH), Vitality (VT), Social Functioning (SF), Role Limitations Related to Emotional Problems (RE), and Mental Health (MH). Such a scale is indicative of the cognitive satisfaction of one's life post mTBI; after 6 to 12 months the patients reported a significant range of scores [6] (Table2).

Behavioural Changes in Patients Diagnosed With PTSD Associated with mTBI

According to Haagsma et al., a variant of behavioural changes was

Table 1: Summary of reviewed cognitive articles.

Author	Year of publication	N	Cognitive assessments	Outcomes
Haagsma et al.	2015	3631	GOS-E	Lowe functional outcomes related to PTSD associated with mTBI.
Haarbauer-Krupa et al.	2015	280	GOS-E RPQ-13 TMT Part A & B CVLT-II WAIS-PSI	Lower scores on the GOSE scale are associated with higher symptoms of PTSD. Showed a high rate of persistent post-concussive symptoms. Lower executive functioning and flexibility. Lower verbal learning and memory. Lower nonverbal processing speed.
Pineau et al.	2014	75	WAIS-III: (Digit Symbol Test) Stroop Task CVLT-II	All clinical groups showed significant slowness on the visual graphic task. Both in colour naming and reading conditions, the mTBI\PTSD group was significantly slower than the other clinical groups. Only the mTBI\PTSD group had a significantly weaker mean than the control group.
Pineau et al.	2015	75	CFQ	Patients with PTSD associated with mTBI had significantly lower GOSE scores compared to TBI without depression and probable PTSD (6 months).
Winkler et al.	2017	93	GOS-E	PTSD associated with mTBI is significantly related to lower scores on GOS-E.

N: number of participants, GOS-E: Glasgow Outcome Scale-Extended, CFQ: Cognitive Failure Questionnaire, CVLT-II: The California Verbal Learning Test, Second Edition. TMT: Trail Making Test Part A & B. WAIS-III: Wechsler Adult Intelligence Scale, Third Edition. WAIS-PSI: The Wechsler Adult Intelligence Scale, Fourth Edition, processing speed index. RPQ-13: Test Rivermead Post-Concussion Questionnaire-13. PSI: The Processing Speed Index.

Table 2: Summary of reviewed psychological articles.

Author	Year of publication	N	Cognitive assessments	Outcomes
Choi et al.	2014	71	PCL-C	The PCL-C scores were shown to be strongly predictive for PTSD screening in patients with mTBI.
Haagsma et al.	2015	3631	PQoL:(PF, RP, BP, GH, VT, SF, RE, MH). BDI-II IES	Patients who followed up after 6 months reported their dissatisfaction with their function ranging from 53 to 100%, while after a 12-month follow-up patients' dissatisfaction became wider in the range from 25 to 100%. The mean of BDI-II scores showed high percentages after 12 months in patients diagnosed with PTSD associated with mTBI. Patients that scored higher than 35 on IES expressed more symptoms that are indicative of PTSD.
Haarbauer-Krupa et al.	2015	280	PCL-C BSI-18 SWLS	The incidence of PTSD symptoms following mTBI for 6 months was significantly positive. There was an indication of psychological distress. Lower satisfaction with life.
Pineau et al.	2014	75	BDI-II and STAI	Patients in the mTBI\PTSD group were significantly more depressed and anxious than those in the control and mTBI groups.
Pineau et al.	2015	75	FrSBe BDI-II and STAI	Higher scores were indicative of greater behavioural changes. Higher indications of both depressive and anxious symptoms were significantly shown in the mTBI\PTSD group than in the control group.
Winkler et al.	2017	93	PCL-C	Patients who carry COMT Met158 showed low symptoms of PTSD following mTBI.

N: number of participants, PCL-C: PTSD-Checklist Civilian Version. FrSBe: Self-Report of Frontal Behaviour. PQoL: Perceived Quality of Life Scale (PF: Physical functioning. RP: Role limitations related to physical health problems. BP: Bodily pain, GH: General health perception. VT: Vitality. SF: Social functioning. RE: Role limitations related to emotional problems. MH: mental health). BSI-18: Validity of the Brief Symptom Inventory-18. SWLS: The Satisfaction with Life Scale. BDI-II: The Beck Depression Inventory. STAI: State-Trait Anxiety Inventory. IES; The Impact of Event Scale.

observed and reported in patients following mTBI. Data was collected based on follow-up questionnaires at 6 months and 12 months. The questionnaire assessed items including "sociodemographic (age, sex, educational level, and household composition), medical consumption, clinical outcome, functional outcome, health-related quality of life and self-report inventories on depression and anxiety". For instance, patients who responded to the 6-month follow-up questionnaire of post-TBI were admitted to the hospital and the ICU. In comparison, patients who filled out the 12-month follow-up questionnaire were more likely to be admitted to the hospital. Using such information alongside different assessments of the psychological impact of TBI and PTSD on patients, certain psychological disorders have been detected including depression and anxiety. Patients who showed symptoms of depression were assessed using the Beck Depression Inventory (BDI-II) alongside assessing them with The Impact of Event Scale (IES) to assess their post-traumatic stress, which is indicative of PTSD [6] (Table 2).

Based on the data that was collected from both the follow-up questionnaires at 6 months and 12 months, the BDI and IES scores were available for 92% and 96% of the patients who filled out the 6 months questionnaire. In contrast, after 12-month BDI-II and IES-scores were available for 97% and 99% of the patients. Patients who scored 19 on the BDI or more were more likely to be diagnosed with depression, whereas patients who scored 35 or higher on the IES were more likely to be diagnosed with PTSD [6].

However, according to the data collected from the 6-month follow-up 6.5% of patients had depression and 8.7% had probable PTSD. Where around 3.4% of the patients met the criteria of both depression and probable PTSD. Moreover, patients who finished the 12-month follow-up had an average of 6.8% and 8.5% of which had depression and PTSD. And 2.5% met the criteria of both depression and PTSD. Further, after 6 months 11.8% of patients have a prevalence rate of IES and/or BDI score that suggests the diagnosis of both PTSD and/or depression. On the other hand, in the 12-month follow-up questionnaire, patients who have been diagnosed with depression and/or PTSD had an average of 12.8%. According to the State-Trait Anxiety Inventory (STAI), measures were indicative of the intensity of anxiety symptoms in patients with PTSD following mTBI. Such

participants were under major stress following their incidents, which contributed to many psychological symptoms including those of what was discussed above [6,12] (Table 2).

Another parameter that was used in a study done by Pineau et al. is the Self-Report of Frontal Behaviour (FrSBe), indicating high scores indicative of greater behavioural changes. It consists of 46 items divided into 3 sub-scales: apathy, disinhibition, and executive scales. Higher scores were indicative of greater behavioural changes, and the study reported significant behavioural changes in the clinical groups rather than the control group [12].

Haagsma et al. used a neuropsychological battery to assess behavioural changes in PTSD patients associated with mTBI, including PCLC, Validity of the Brief Symptom Inventory-18 (BSI-18), and the Satisfaction with Life Scale (SWLS). According to their research, the neuropsychological battery assessment showed significant scores (Table 1 & Table 2).

From the review above, it appears that the various studies that reported cognitive and behavioural changes that occurred in patients diagnosed with PTSD associated with mTBI demonstrated a significant impact on patients' psychological and functional outcomes. Cognitive changes that were reported in various studies included attention deficit, low executive function and flexibility, verbal learning, memory, as well as non-verbal processing speed. Where some studies demonstrated behavioural changes such as depression, anxiety, and lower satisfaction with life.

Furthermore, various articles examined the countereffects of PTSD and mTBI on one another, yielding such information from cognitive and behavioural parameters that were implemented on a group of patients.

Discussion

To our knowledge, this is the first review of the existing articles investigating the cognitive and behavioural impact of the development of PTSD associated with mTBI patients. Based on the 6 articles reviewed, the major findings were: (1) The severity of PTSD symptoms depends on various factors; (2) the correlation between GOS-E scores and worsening the Symptoms of PTSD; (3) the cognitive changes after the development of PTSD associated with mTBI; (4) the behavioural changes after the development of PTSD associated with mTBI.

Most of the previous studies have illustrated the impact of mTBI on patients and the possible development of PTSD following their incidents within the civilian population. It can be argued that severe to moderate TBI affects patients' consciousness and elicits memory deficits, which could prohibit patients from developing PTSD, yet in cases of mTBI, such cognitive functions remain somehow intact allowing the development of cognitive changes and PTSD. Cases of mTBI put patients under stressful and fearful events, physical stress, and injuries such as falling, assault, road traffic accidents, blunt trauma to the brain and unknown traumatic events [12].

Deeper perception of mTBI on patients has been discussed in various researches and systematic reviews, which include the neuropsychological and functional outcomes, the severity of symptoms of PTSD, GOS-E scores outcomes, severity of the impact, genetics, the post-traumatic period, as well as the quality of life following the diagnosis of PTSD. Post-traumatic stress disorder is a group of diseases of patients experiencing a serious traumatic incident, which leads them into developing multiple symptoms of PTSD such as being fearful, experiencing repetitive recollection of the incident and avoidance. Such patients get evaluated and assessed using multiple scales to be diagnosed with PTSD as well as assessing their consciousness and cognitive and behavioural changes [4]. An analysis that was done by Winkler et al. suggests that PTSD and GOS-E scores are inversely associated with one another. This supports our hypothesis of PTSD impacting on the cognitive and behavioural status of patients following mTBI since GOS-E scores are assessing the intact cognitive function of such individuals [12,17].

The lower the score of GOS-E the higher the association of worsening the symptoms of PTSD. The results of the study done by Pineau et al. highlight the impact of PTSD post-mTBI and the cognitive deficit patients reported. The results indicated a greater cognitive deficit. The results suggested that the PTSD group had significantly greater deficits in some measures of decreased concentration, attention deficit, and reports of agitation. Although such results can be impacted based on the quality of life each individual is experiencing as well as dealing with other comorbidity conditions including depression and anxiety prior to the diagnosis of PTSD following mTBI. This raises the answer to the question if there are cognitive and behavioural changes after the development of PTSD following mTBI. There is an urgent need for thorough further assessment of patients after the development of PTSD associated with mTBI, to further discuss the wider impact it contributes to their quality of life, their functional outcome, cognitive outcome, behavioural outcomes, and the pre-existing comorbidity of PTSD with depression on patients with mTBI.

In the event of living with existing psychological comorbidity such as depression, anxiety, and PTSD\mild PTSD when it is added to mTBI it leads to various cognitive and behavioural changes including those affecting the verbal long-term memory of mTBI patients [12]. The study done by Pineau et al. discusses the possible differences in severity of PTSD in patients following their mTBI. Mild traumatic brain injury and PTSD patients might develop cognitive and behavioural changes; however, the severity of PTSD holds a greater significance in determining the amount of cognitive and behavioural change patients with mTBI would experience.

Genetic mutations play a role in developing PTSD in patients with mTBI. For instance, patients with COMT VAL 158 mutation and variations have a higher possibility of developing PTSD associated with mTBI. Producing the conclusion that multiple baseline triggers and risk factors do contribute to the overall status of patients with post-mTBI as well as the severity of PTSD alongside various cognitive and behavioural changes [17]. Further research expanding the view of different triggers and risk factors can elaborate on the wide spectrum of PTSD diagnoses, and the greater impact it has on patients who have experienced mTBI regardless of pre-existing comorbidity conditions such as depression and anxiety.

Based on the previous research, depending on the four groups of participants that underwent the study, multiple symptoms a rose that needed further evaluation and categorisation into the PTSD

diagnosis. A percentage of 4% didn't meet the criterion for PTSD, yet they experienced a great impact and reported subclinical symptoms. According to the outcome results after assessing patients by SCID-1, the PTSD group and the PTSD\mTBI group of participants displayed a greater prevalence of moderate and severe PTSD. Such variations of symptoms indicate the intensity of PTSD development following mTBI. Various symptoms may arise following mTBI, which are similar to PTSD symptoms, including dizziness, headaches, irritability, memory, and consciousness. Such symptoms may exacerbate into chronic symptoms and sometimes undergo the possibility of overlapping with PTSD symptoms, giving rise to a serious clinical point that needs to be taken into consideration while diagnosing mTBI patients with PTSD [12,13]. Even though there is significant comparability between the symptoms of mTBI and PTSD it is important to discuss the differential clinical diagnoses.

A description of the cognitive and behavioural changes was discussed in the study done by Pineau et al. PTSD patients who have been subjected to the FrSBE reported multiple perceived behaviour changes including apathy, disinhibition, and executive dysfunction; post-mTBI. Such changes are significantly affecting the quality of the patient's life; post-trauma. This further supports our hypothesis of the greater impact of PTSD associated with mTBI in affecting the patients' functional cognition and behaviour after their traumatic event. The change in the neuropsychological status of patients after the incident has a major role in affecting the quality of life of patients.

Given the findings of the current reviews, the mTBI group of participants that were assessed using PQoL reported multiple health domains that were affecting their quality of life including PF, RP, BP, GH, VT, SF, RE, and MH. Furthermore, the mental and physical health of patients diagnosed with PTSD associated with mTBI is proportionally affected by the quality of life and vice versa [6]. This introduces the question of whether the PTSD symptoms alone have an impact on the functional health of mTBI patients and if their consequences further decrease the satisfaction of their quality of life after the traumatic incidents. It raises the importance to further evaluate mTBI patients on their PTSD symptoms and other clinical symptoms unrelated to PTSD that worsen the severity of PTSD as well as the quality of life.

Limitations

This review of the literature illustrates studies that have investigated the cognitive and behavioural changes in the development of PTSD associated with mTBI in the civilian population. However, the majority of these studies focused on the probability of developing PTSD in association with TBI patients with no further discussion on the cognitive and behaviour changes after developing PTSD associated with mTBI. Prior research has provided evidence that numerous neuropsychiatric symptoms and disorders are associated with TBI. These symptoms and disorders are either independent entities or co-occurring with PTSD. In addition, there are some studies that have reported that patients with TBI are at a high risk of developing PTSD, there was no further discussion addressing the risk associated with developing PTSD in TBI or mTBI patients. Moreover, most previous studies have carried out their research based on veterans and military personnel after the development of PTSD associated with mTBI, creating a limitation in civilian-associated research.

Recommendations

Future studies should take all the limitations highlighted above into account and further enhance the civilian data available to support future studies discussing PTSD associated with mTBI. It was evident that there are no studies investigating the risks associated with TBI or mTBI and their association with developing PTSD. Therefore, future researchers need to further investigate the risk factors and risks associated with the development of PTSD associated with mTBI.

There is a need to expand and demonstrate the cognitive and behavioural changes associated with PTSD after mTBI. Many of the recent systematic reviews do not cover the cognitive and behavioural changes that may arise after the development of PTSD associated with mTBI.

It is important to take into consideration the possibility of a pre-existing diagnosis of PTSD in patients who have a recent mTBI that leads to the development of PTSD symptoms related to their recent trauma. The previous line suggests the possibility of mistreatment and misdiagnosis, which contributes to the overall clinical outcome. There is a need for a thorough evaluation of mTBI patients on their symptoms and correlating them with PTSD or other clinical disorders unrelated to PTSD that may affect their quality of life, which further on, enhances the significance of the treatment plan for mTBI patients who are diagnosed with PTSD and their follow-up to manage their symptoms and enhance their quality of life such as improving their cognitive function, verbal long-term memory, attention span and concentration, and their disinhibition, as well as impacting their mental health status, which includes improving their agitation and social withdrawal, apathy, and most importantly depression, anxiety alongside PTSD.

Conclusion

We concluded that there is a major limitation in this area of research, especially with mTBI and their greater possibility to develop PTSD in comparison to moderate to severe TBI. The development of PTSD associated with mTBI is a serious positive possibility that needs to be considered for clinical practitioners and researchers to pay close attention to. In our review, we discussed the possibility of the cognitive and behavioural changes in PTSD patients associated with mTBI that further affect their PQoL.

The pre-existing psychological comorbidity such as PTSD itself and depression do have a significant impact on the overall health outcomes of PTSD-diagnosed patients following mTBI. We found that mTBI patients scoring lower in the GOS-E inversely related to being diagnosed with PTSD score even lower in mental parameters such as FrSBe and CFQ. As discussed above, as this study included six studies, further investigations are needed to further expand our findings and enhance information regarding the cognitive and behavioural impact of PTSD associated with mTBI.

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References

1. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders, 5th Edition: DSM-5 (5th ed.). American Psychiatric Publishing. 2013.
2. Bray NJ, O'Donovan MC. The genetics of neuropsychiatric disorders. Brain and Neuroscience Advances. 2019; 2: 239821281879927.
3. Bryant RA, Harvey AG. The influence of traumatic brain injury on acute stress disorder and post-traumatic stress disorder following motor vehicle accidents. Brain injury. 1999; 13: 15-22.
4. Choi MS, Seo SJ, Oh CH, Kim S, Cho JM. Incidence of Post-Traumatic Stress Disorder after a Mild Traumatic Brain Injury: Preliminary Investigation Using the Brief Neuropsychological Screening Test. Journal of Korean Neurosurgical Society. 2014; 55: 190.
5. Dewan MC, Rattani A, Gupta S, Baticulon RE, Hung Y, Punchak M, et al. Estimating the global incidence of traumatic brain injury. Journal of neurosurgery. 2018; 130: 1080-1097.
6. Haagsma JA, Scholten AC, Andriessen TMJC, Vos PE, Beeck EFV, Polinder S. Impact of depression and post-traumatic stress disorder on functional outcome and health-related quality of life of patients with mild traumatic brain injury. Journal of neurotrauma. 2015; 32: 853-862.
7. Haarbauer-Krupa J, Taylor C A, Yue J K, Winkler E A, Cooper S, Stein M, et al. Screening for Post-Traumatic Stress Disorder in a Civilian Emergency Department Population with Traumatic Brain Injury. Archives of Physical Medicine and Rehabilitation. 2015; 96: e4.
8. Iljazi A, Ashina H, Al-Khazali HM, Lipton RB, Ashina M, Schytz HW, et al. Post-Traumatic Stress Disorder After Traumatic Brain Injury—A Systematic Review and Meta-Analysis. Neurological Sciences. 2020; 41: 2737-2746.
9. Koenen KC, Ratanatharathorn A, Ng L, McLaughlin KA, Bromet EJ, Stein DJ, et al. Posttraumatic stress disorder in the World Mental Health Surveys. Psychological Medicine. 2017; 47: 2260-2274.
10. Loignon A, Ouellet M, Belleville G. A Systematic Review and Meta-analysis on PTSD Following TBI Among Military/Veteran and Civilian Populations. Journal of Head Trauma Rehabilitation. 2019; 35: E21-E35.
11. Md N Z D, Md K D I, Do R Z D. Brain Injury Medicine, Third Edition: Principles and Practice (3rd ed.). Demos Medical. 2021.
12. Pineau H, Marchand A, Guay S. Objective Neuropsychological Deficits in Post-Traumatic Stress Disorder and Mild Traumatic Brain Injury: What Remains Beyond Symptom Similarity?. Behavioral Sciences. 2014; 4: 471-486.
13. Pineau H, Marchand A, Guay S. Specificity of Cognitive and Behavioral Complaints in Post-Traumatic Stress Disorder and Mild Traumatic Brain Injury. Behavioral Sciences. 2015; 5: 43-58.
14. Rogers JM, Read CA. Psychiatric comorbidity following traumatic brain injury. Brain Injury. 2007; 21: 1321-1333.
15. Tanev KS, Pentel KZ, Kredlow MA, Charney ME. PTSD and TBI co-morbidity: Scope, clinical presentation and treatment options. Brain Injury. 2014; 28: 261-270.
16. Vasterling JJ, Jacob SN, Rasmusson A. Traumatic Brain Injury and Posttraumatic Stress Disorder: Conceptual, Diagnostic, and Therapeutic Considerations in the Context of Co-Occurrence. The Journal of neuropsychiatry and clinical neurosciences. 2018; 30: 91-100.
17. Winkler E A, Yue J K, Ferguson A R, Temkin N R, Stein M B, Barber J, et al. COMT ValMet polymorphism is associated with post-traumatic stress disorder and functional outcome following mild traumatic brain injury. Journal of Clinical Neuroscience. 2017; 35: 109–116.