

Original Article

A Systematic Review of Personality Changes after Mild-to-Severe Traumatic Brain Injury

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Abstract

Background and Aim: Personality changes (PCs) following traumatic brain injury (TBI) can exacerbate a frequently widespread range of symptoms, including problems in behavioral responses and emotion and reduced activity levels. This study aimed to systematically review the PCs in people with mild to severe TBI.

Materials and Methods: A systematic literature search was conducted in PubMed, Web of Science, Scopus, and Google Scholar using MeSH and free text terms between 1998 and 2024. Of the 1160 articles identified, 768 studies remained after duplicate studies were removed. The abstracts and full text of the search results were screened using Rayyan QCRI Intelligent Systematic Review.

Results: A final 67 studies were retrieved for full-text screening that met the inclusion criteria. After renewed screening, 27 studies were included in this review. The pooled sample size was 50369 participants aged 16-79 years. In addition, 25, 11, and 3 percent of the studies included all intense, severe, and mild TBI, respectively. Although several studies recognized personality changes between 3.5 and 88% in individuals with TBI, aggressiveness with 33% frequency is the most common personality change following traumatic brain injury in all intensities.

Conclusion: Research showed that changes in personality and behavior can be due to the injury at a natural level, as well as the patient's response to the injury and the subsequent disabilities they may encounter. Moreover, the high frequency of reported personality disorders indicates that there is no distinct personality syndrome after TBI, which is personalized for each person and has an effect on their quality of life and daily functioning. Hence, to accurately diagnose and implement treatment interventions early and effectively, it is crucial to acknowledge and explain the symptoms, outcomes, phenomenology, and characteristics of deficits caused by TBI.

Keywords: Traumatic brain injury, Personality changes

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Introduction

Traumatic brain injury (TBI) represents one of the most fatal and incapacitating conditions globally, impacting individuals of all age groups, including children, working-age adults, and older adults (1). Approximately 70 million individuals worldwide suffer from TBI annually (2). With a global burden of nearly 27 million cases per year (3), TBI exerts significant physical, psychosocial, and economic impacts on patients and their families (2). TBI is defined as an “alteration in brain function, or other evidence of brain pathology, caused by an external force” (4), and it can result in vascular and axonal injuries, edema, and neuro cell death (5). Consequently, it initiates a cascade of pathological events, including disrupted local neural activity and impaired neural networks (6). These complications can detrimentally affect various aspects of the individual’s functionality and lifestyle (7), constituting a significant public health concern with potential long-term effects that may not be immediately apparent in its clinical presentation (8). Emerging evidence suggests that even mild and recurrent TBI can lead to gradual progressive impairment (9). Indeed, severe or chronic conditions may demonstrate complete recovery, whereas conditions perceived as mild can result in incapacitating consequences (10). As such, TBI, which causes lifelong neural impairment, could be regarded as a chronic lifelong disease (10). The interplay between various physical, cognitive, and emotional symptoms following TBI exacerbates the condition (11). Hence, a prognosis of neural factors (such as severity, etiology of TBI, etc) is well-recognized in determining outcomes like survival and functional status. However, the differences in quality of life and psychological well-being before and after the injury cannot be explained by the neural factors alone (12). Therefore, it is crucial to understand the characteristics that predispose individuals to poor psychological consequences to guide focusing on early interventions (13).

Although early psychological research on the severe effects of TBI usually concentrated on cognitive functions, there has been an increasing focus on the extensive behavioral outcomes associated with TBI in

recent decades (14). For many patients, these behavioral consequences pose more challenges than the physical disabilities resulting from TBI, and vital life consequences often manifest as relational difficulties, social isolation, and unemployment (15). Significant changes in behavioral responses following TBI are frequently described as personality change (PC) by survivors and their caregivers (16). Personality change is generally expected to occur gradually over a long time; however, rapid and dramatic changes can occur when change is actively worked on or due to biologically mediated processes (17). In other words, PC is a prevalent and debilitating disorder that occurs after numerous neural disorders and is associated with reduced activity levels, increased social problems, unemployment, lower quality of life, and increased familial burden in individuals suffering from TBI (18). Personality encompasses patterns of thinking, feeling, and behaving that remain relatively stable. These traits shape our expectations, values, and views and can predict our reactions under various conditions (13). They function as windows through which we perceive and interpret daily experiences, continually updating our self-knowledge and beliefs (7). While personality traits are generally considered stable, research has shown that they can change throughout a person’s life and in response to significant life events. Moreover, individuals with chronic diseases experience more pronounced PC than those undergoing natural aging (12).

As TBI is recognized as a neural disorder, PC may result from damage to brain structures that support the processes of cognitive, emotional, and behavioral foundations of personality (19). Consequently, over half of individuals with TBI report changes in at least a few personality traits (20), perceiving substantial differences between their pre- and post-injury selves (12-15). These changes can persist for years following the initial injury (21). Post-TBI behavioral manifestations include PC, depression, anxiety, impulsivity, irritability, emotional instability (11), inhibited and inappropriate social behavior, demotivation (22), and recurrent unawareness of these changes (16). The experience of these changes is inherently negative and anxiety-inducing, leading to avoidance and reduced activity (23). Thus, the emergence of disinhibition, apathy, suspiciousness, or

aggression following TBI has been included in the DSM-5-TR as symptoms for diagnosing PC due to other medical conditions (24).

TBI can lead to various behavioral and emotional disorders, with symptom manifestation depending on the specific brain regions affected (25). This pattern of behavioral changes is supposed to reflect particular frontal-subcortical dysfunction, areas especially vulnerable to TBI (16, 21). Previous research has demonstrated that PC is evident across all dimensions of the Big Five Personality Traits—neuroticism, extraversion, conscientiousness, openness to experience, and agreeableness—following brain injury. Specifically, increased neuroticism has been observed in individuals with frontotemporal damage (20). Consequently, repeated trauma to these brain regions in subsequent stages may result in chronic traumatic encephalopathy, a progressively deteriorating neurological condition that can also be associated with PC, as well as Parkinsonism and dementia (26, 27). Despite the recognition of PC following brain injury, comprehensive examinations of its frequency and extent across different severity levels remain limited. Previous research has examined the personality traits of individuals after mild TBI (mTBI) (28), and a few studies have assessed a comprehensive set of personality and psychological traits in a specific sample (29). However, no studies have comprehensively examined the frequency and extent of post-TBI PC across different levels of severity. Given the limited research on post-TBI PC, this study aimed to systematically review the Personality Changes at all severities of TBI.

Methods

The studies included in this review were 1. articles published in English and Persian, 2. Reporting a completed research, 3. Only studies published from 1998 onward and before the first March 2024, 4. Participants in the studies had to be at least 16 years old (to avoid confounds associated with the personality in children and adolescents), 5. evidence of TBI had to be determined by using one or more of the following methods: 1. Glasgow Coma Scale, 2. reported loss of consciousness (LOC) or evidence of posttraumatic amnesia (PTA), 3. clinical or

neuroimaging diagnosis.

Studies or papers that did not fall within the above criteria were excluded. No geographical exclusions were applied. Moreover, the studies were excluded if: 1. Study protocols, literature review, methodological papers, or conference abstracts were excluded (after additional research had been performed to ensure that full papers had not been subsequently published), 2. Articles not measuring personality changes, 3. Longitudinal studies where the sample consisted of participants who were children at the time of TBI.

Search strategy

The initial study was conducted in March 2024, and an updated review was conducted on 1 April 2024. Titles and abstracts were screened using PubMed, Web of Science, Scopus, and Google Scholar for the inclusion of two concepts, TBI and emotion regulation. In addition, articles or reference lists were hand searched to identify either keywords or combinations of keywords (30). The following keywords or MeSH (Medical Subject Headings) terms were used in the database searches: personality, personality change, brain injury, traumatic brain injury.

The completed search results were downloaded into Endnote X9 for citation management and de-duplication. Screening was also performed using a web-based screening program called Rayyan QCRI (Qatar Computing Research Institute) Intelligent Systematic Review (31). Rayyan allows abstract and full-text screening of trials according to user-defined inclusion and exclusion criteria. Firstly, duplicate reports were eliminated; then, studies were screened using the inclusion/exclusion criteria described in the previous section on title and abstract only; in addition, studies that were borderline for inclusion were screened more thoroughly by examining their full text. In addition, the reference lists of the studies were checked for related studies that were not included in the search. As a first step, both reviewers screened all references for titles and abstracts and retained eligible articles. The reviewers then assessed the eligibility of the full-text manuscripts for the articles that remained after the abstract screening. While the final articles were identified for inclusion, the extraction of relevant data was carried out independently by two reviewers. Any disagreements at any stage of the review process were resolved by consensus.

Data extraction

The following information was extracted from each paper:

1. Citation information of the article (including author name/s and the year of publication)
2. The country or region where research has been done there.
3. Study design
4. The aim of study
5. Number of participants in each group that participants in the study
6. Subtypes of CVD that participants affected, if reported
7. Severity of CVD, if reported
8. Percentage of participants who lost to follow-up
9. Mean age for each group.
10. The severity of TBI or mean of GCS, if reported (was not mean TBI severity reported in the study, GCS, or PTA were used in order to calculate the mean severity by the reviewers)

11. The TBI-caused category (the most three frequent reasons reported in the study), if reported
12. The measures that have been used in order to diagnose personality changes
13. The key result of each study

Results

A total of 1160 articles were identified: 245 from Google Scholar, 584 from PubMed, 137 from Web of Science, and 194 from Scopus. After removing duplicate studies, 768 remained, and the abstracts were carefully screened and evaluated. From these, 701 were excluded (8<age<16; 33 animals statistical population; 145 wrong study population; 361 evaluated personality features or did not assess personality changes; 153 Abstracts of conferences or congresses, case reports, reviews, and book chapters) (see flow chart Figure 1).

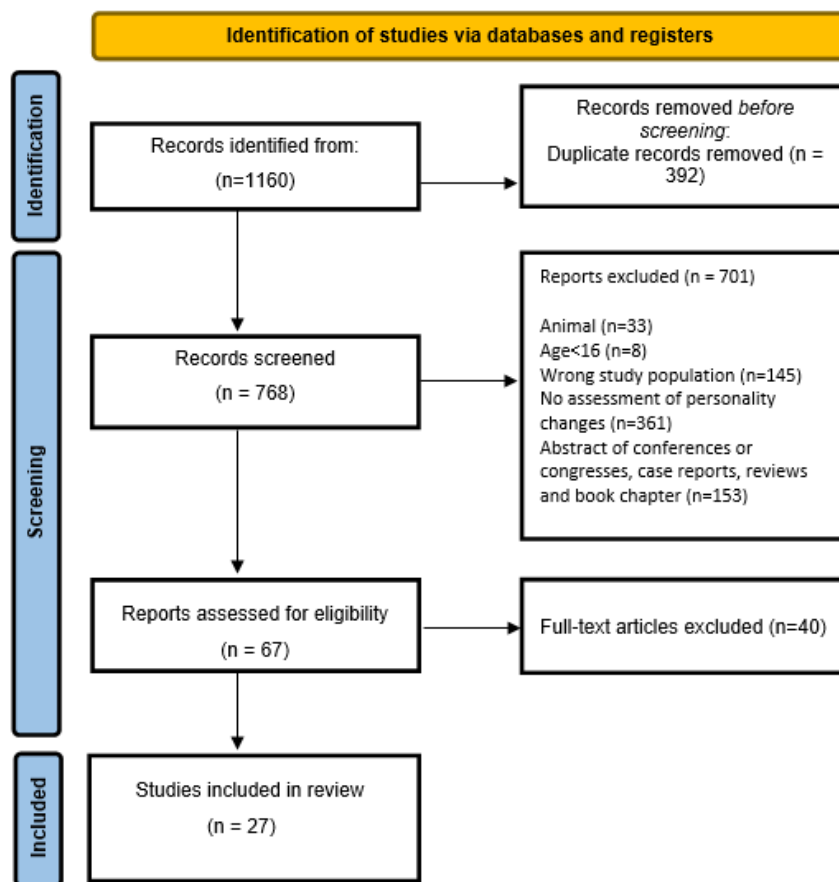


Figure 1. Flow chart of study selection

A final 67 studies were retrieved for full-text screening. Of these, 40 were excluded because, on further review, they did not include an assessment of personality change after injury or its outcome, and they did not include TBI participants. A total of 27 studies were still included in this review.

Table 1 summarizes the main features of the studies included in the systematic review. Moreover, the pooled sample size was 50369, with individual sample sizes ranging from 18 to 40737 in different studies. In addition, most studies ($n=15$, %55) were published between 2010 and 2023. The countries in which the studies were performed were dispersed geographically, %40 studies were conducted in The United States, %18 in Canada, %11 in the United Kingdom, %7 in Brazil, %7 in Australia, %3 in Iran, %3 in Denmark, and %3 in Spain. Seven studies included a mixed sample of the spectrum of traumatic

brain injury (mild, moderate, and severe) (%25). Six studies included moderate and severe types of traumatic brain injuries (%22). Two studies included moderate and mild types of traumatic brain injuries (%7). Three studies included severe types of traumatic brain injuries (%11). one study included mild kinds of traumatic brain injuries (%3). Nine studies included traumatic brain injury survivors and their caregivers, families, or control healthy group (%33). One study included a sample of traumatic brain injury and psychiatric patients (%3). Nine studies (33%) have shown that aggressiveness is the most common and bold personality change following traumatic brain injury in all intensities. Seven studies (25%) reported people with TBI had shown personality disorder after head trauma. Moreover, four studies (14%) reported no personality changes in the range of 4.5% to complete without any personality changes following TBI.

Table 1. Summarize the main features of the studies

Authors (year)	country	TBI sample	Symptom duration years (SD) (range)	Type of severity %	Mechanism of TBI (up to 3 most frequent) %	design	Personality measurement	Mean age (SD) (range)
Rezaei and et al (2012) (32)	Iran	155 TBI	145±53 days	Mild: Aggressive: 71.9% Non-aggressive: 60.7% Moderate: Aggressive: 14% Non-aggressive: 22.5% Severe: Aggressive: 14% Non-aggressive: 16.9%	Motor vehicle accident: 26.9% Motorcycle accident: 25.6% Pedestrian accident: 20.2%	Descriptive-longitudinal	Clinical structured interview (based on DSM-IV-TR ¹) GHQ ² -28	36.7±1.7
		Results	39.4% of people with TBI showed personality changes after 4 months of head injury 30% of patients reported secondary depression after TBI was significantly associated with aggressive behavior					

¹ Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision

²General Health Questionnaire

Velikonja and et al (2010) (33)	Canada	432 68%TBI 32% nontraumatic	3.87 (6.34)	13-15: 18 (4%) 9-12: 12 (2%) 9-0: 32 (7%) No record taken: 370 (85%)	68% of TBI: Motor vehicle accidents Falls Assaults	Quantitative Cross-sectional	PAI ¹ DSM axis 1 and/or 2	15-69
	Results	This study found that 50% of the TBI sample had emotional and behavioral problems. Depression and somatic symptoms were most prevalent in the TBI sample, showing high levels of internalizing symptoms and a more complex profile combining affective, cognitive, and personality disorders.						
Seel and Kreutzer (2003) (34)	USA	172	27.8±43.8 month	10.51±4.4 (44% severe)	Vehicle: 68% Violence: 13% Fall: 12%	Quantitative Cross-sectional	MMPI-2 ²	36.5±12.2 (16-75)
	Results	Results of MMPI-2 have shown that 83% of patients were depressed and 75% of TBI sample were normal with no personality changes.						
Konop M. and et al. (2022) (35)	Poland	3929	NA	NA	NA	Quantitative Cross-sectional	checklist KO "0" structured interview (Life Questionnaire)	Woman: 33 SD:9 Men: 32 SD: 9
	Results	Patients with a history of head trauma have a higher overall severity of neurotic disorder symptoms than patients without such a history. A significant relationship was found between head trauma and a range of anxiety, somatization, and conversion symptoms.						
Ruocco and et al. (2007) (36)	USA	TBI: 231 Psychiatric patients: 1517	NA	Mild: 84% Moderate: 16%	Motor vehicle accidents: 74.8% Falls: 11% Blows to the head (10.6%)	Quantitative Cross-sectional	MCMII-III: self-report DSM-IV personality disorders (Depressive, Sadistic/Aggressive and Masochistic/Self-Defeating personality disorders)	TBI: 41 Psychiatric patient: 45.1 SD: 12.9 (18-86)
	Results	Prevalence of antisocial, aggressive, schizotypal, paranoid, borderline, bipolar: mania, drug dependence, thought disorder, and delusional disorder were below 10%, and Schizoid, avoidant, depressive, dependent, histrionic, narcissistic, compulsive, passive-aggressive, masochistic, somatoform, PTSD, major depression were above 15% and anxiety, and dysthymia was approximately 50% in TBI sample.						
Rodríguez-Bailón and et al. (2012) (37)	Spain	9 TBI with prefrontal brain damage 9 Neurologically intact individuals	NA	NA	NA	Quantitative Cross-sectional	Neuropsychological assessment The Millon Multiaxial Clinical Inventory (MMCI-II) Diagnostic and Statistical Manual of Mental Disorders or DSM-IV-TR	Control group: 30.89 (SD=8.07) TBI:29.4 (SD=6.97)
	Results	The results showed that the group of patients with prefrontal lesions had greater interference that was associated with personality measures related to cognitive and behavioral impulsivity and rigidity. The personality changes secondary to prefrontal cortex damage, characterized by behavioral disinhibition and impulsivity, and the borderline personality was correlated with TBI significantly (p=0.006)						

¹Personality assessment inventory²Minnesota Multiphasic Personality Inventory-2

Weddell and et al. (2016) (38)	UK	57 ML ¹ claimants who were referred by their solicitor and who passed two effort tests (Word Memory Test and Test of Memory and Malingering) 64 patients referred by NHS ² doctors to a sub-regional Neuropsychology Department	NHS: 64.5 (5-215) ML: 49.3 (10-210)	GCS means NHS: 9 ML: 8.7 (Moderate 8 severe 63)	Vehicle accident: (NHS: 45%, ML: 87.1%) Fall: (NHS: 30%, ML: 9.6%) Assault: (NHS: 17.5%, ML: 3.2%)	Quantitative Cross-sectional	Zoo Map BADS ³ DEX ⁴ BIS ⁵ -11 STAXI-II ⁶	NHS: 39.8 (19-58) ML: 33.8 (19-63)
		Results	Significant personality changes were frequently reported (67.6%). The study has shown that 9.9% of the sample had no personality change, 22.5% a little, 47.9% a lot, and 19.7% of patients had personality changes completely. Of the 64 instances of PC, the change was seen as being highly desirable (3.1%), desirable (10.9%), desirable in some respects but not in others (46.9%), undesirable (31.3%) and highly undesirable (7.8%).					
Diaz and et al. (2014) (39)	Brazil	135	NA	Severe	Motorcycle crash: 39.5% Automobile crashes: 23.2% Falls: 16.3%	Quantitative Cross-sectional	DSM-IV Axis I Disorders (SCID-I) Hospital Anxiety and Depression Scale (HADS)	31±12
		Results	According to DSM-IV-TR, 23.6% of patients had personality changes, 6 patients were apathetic (42.8%), 3 were aggressive (21.4%), 3 were disinhibited (21.4%), and 2 (14.4%) were of mixed subtype (apathy/aggression). Also, 20.9% and 1.6% of patients had shown anxiety disorder and alcohol/other drug disorder respectively.					
Till and et al. (2009) (40)	Canada	61	119.0 days (SD= 122.2) (32–496)	Mean GCS: 52 (85% participants) was 7.11 (SD= 3.7) moderate to severe	Motor vehicle accidents: 61.7% Falls: 30.0% Assaults: 6.7%	Quantitative Cross-sectional	PAI	38.1 (SD= 15.3) (17–79)
		Results	People with traumatic brain injury often suffer from advanced psychopathology and personality disorders, which may be partly a reflection of psychopathology, mood disorders, or psychological maladjustment; it may be due to the cognitive and physical effects of the injury.					

¹Medico-legal²National Health Service³Behavioral Assessment of the Dysexecutive Syndrome⁴Dysexecutive Questionnaire⁵Barratt Impulsiveness Scale⁶State-Trait Anger Expression Inventory

Greve and et al. (2001) (41)	USA	IA ¹ group: 26 TBI NC ² group: 19 TBI	MIN: 20 months	NA	NA	Quantitative Cross-sectional	EPQ ³ (Neuroticism, Psychoticism, Extroversion) BIS ⁴ BPAQ ⁵	Normal control: 38.9 (SD= 7.42) Impulsive aggressive: 33.9 (SD=10.91)
	Results	74% of the IAs reported problems with aggression and impulsive behavior before their injuries, compared to only 26% of the NCs Compared to non-aggressive control participants, AI participants had higher rates of premorbid aggressive behavior and were currently more impulsive, irritable, and antisocial.						
Demakis and et al. (2007) (42)	USA	95 TBI	±2 Month	NA	NA	Quantitative Cross-sectional	PAI Cluster Morey (1991)	33.4 (15.0)
	Results	Analysis has shown that 76.7% of participants belonged to one of four categories: 34.7% of individuals had no clinically significant psychological symptoms, 18.9% of individuals had social isolation and confused thinking, 12.2% of individuals had depression and withdrawal, and 10.5% individuals had significant physical problems.						
Udala and et al. (2018) (43)	Canada	116	823 days (SD=13.33)	Mild: 44% Moderate: 5.2% Severe: 12.9% Unknown: 37.9%	Motor vehicle related: 77 (66%) Work related: 16 (13%)	Quantitative Cross-sectional	MMPI-2	40.27 (SD=15.32)
	Results	39.7%, 6.9%, 16.4%, 23.3%, and 17.2% of participants exhibited anxiety, fear, obsessive thoughts, depression, and strange thoughts, respectively.						
Mendez and et al. (2012) (44)	USA	blast-force mTBI (n=12) blunt-force mTBI (n=12).	Blast group: 4.31 (1.69) year Blunt group: 4.07 (1.49)	Mild	NA	Quantitative Cross-sectional	IM-P ⁶ BFI ⁷ IAS ⁸ FrSBe ⁹	Blast group: 30.50 (7.97) Blunt group: 30.64 (6.50)
	Results	More negative personality changes occur after head trauma caused by explosive force than by blunt force. Compared to those with mTBI from blunt forces, those with blast-force injury had more anger, frustration, toughness, professional boundary violations, and possibly, anxiety-affective lability such as neuroticism						
Rush and et al. (2006) (45)	USA	39 moderate-severe TBI 20 mild TBI 31 sustained OI ¹⁰ but had no evidence of brain injury	NA	Mild: 14.63 (0.62) Moderate/severe: 10.37 (4.16) OI: -	NA	Quantitative Cross-sectional	Independent Living Scale (ILS) Mayo-Portland Adaptability Inventory (MPAI).	Mild: 37.21 (20.97) Moderate/severe: 38.75 (19.57) OI: 44.78 (18.29)
	Results	There is no consistent evidence that personality scores changed before and after injury in TBI groups. The severity of traumatic brain injury (moderate to severe or severe) influences the magnitude of changes observed between patient groups. Personality abnormalities and personality changes after head injury are usually very mild or, conversely, personality functioning in most people with a head injury is similar to that initially seen after the injury.						

¹Impulsive Aggressive²Non-Aggressive Control³Eysenck Personality Questionnaire⁴Barratt Impulsiveness Scale-11⁵Buss-Perry Aggression Questionnaire⁶Interpersonal Measure of Psychopathy⁷Big Five Inventory⁸Interpersonal Adjectives Scale⁹Frontal Systems Behaviour Scale¹⁰Orthopedics injury

Koponen and et al. (2002) (46)	Canada	60	NA	Mild: 15 (25%) Moderate: 15 (25%) Severe: 11 (18.3%) Very severe: 19 (31.7%)	NA	Quantitative Follow-up	Structured Clinical Interview for DSM-III-R Personality Disorders (SCID-II) Mild Deterioration Battery	60.8 (10.3) (44-48)
	Results	Fourteen patients (23.3%) had at least one personality disorder. The most common individual disorders were avoidant (15.0%), paranoid (8.3%), and schizotypal (6.7%) personality disorders. 9 patients (15.0%) had DSM-III-R organic personality syndrome.						
Holzer and et al. (2019) (47)	USA	40,737 TBI	NA	NA	NA	Quantitative Cross-sectional	NA	18-34: 22.10% 35-49: 26.98% 50 – older: 50.92%
	Results	The adjusted odds ratio (AOR) was calculated at 2.77, 95% CI=2.34-3.29 for disorders of adult personality and behavior in patients with TBI and it has shown a significant associated with a history of head trauma.						
Diaz and et al. (2012) (48)	Brazil	33	18.4±6 month	7 or 8: 20 (41.6%) 5 or 6: 14 (29.2%) 3 or 4: 14 (29.2%)	NA	Quantitative Cross-sectional	DSM-IV Axis I Disorders SCID-I ¹ HRQOL ²	32.3 (11.7)
	Results	The frequency of personality changes was 33.3%. Patients with personality changes showed more apathy and general psychopathology.						
Gagnon and et al. (2005) (49)	Canada	30 TBI 30 controls	0-36 month 3.48 (8.97)	GCS mean: 9.91 Severe: 17 Moderate: 13	Motor vehicle accident: 47% Falls: 30% Road traffic accident: 13%	Quantitative Cross-sectional	Diagnostic Interview for Borderlines-Revised (DIB-R). Fifteen questions from the Structured Clinical Interview for DSM-IV Personality Disorders (SCID-II)	TBI: 26.3 (13.1%) Control: 36.3 (13.3%)
	Results	Thirteen subjects with TBI (43%) were described as having no personality changes. Relatives reported personality changes in 17 (57%) subjects with TBI, which were documented as follows (multiple categories could be assigned to each subject): 13 unstable (43%), eight withdrawn (27%), eight aggressive (27%), five were other (17%), three were apathetic (10%) and two were paranoid (7%).						
Moley and et al. (2022) (50)	USA	Without mTBI 1189 mTBI 267	NA	mild	NA	Quantitative Cross-sectional	DSM-IV Personality (formerly Axis II) Disorder	No mTBI: 34.2±11.0 mTBI: 36.2±10.8
	Results	44.7% of patients without mTBI and 58.8% of patients with mTBI had PD. 5.9% of patients without mTBI and 9.4% of patients in the mTBI group had cluster A disorders including paranoid personality disorder, schizoid personality disorder, and schizotypal personality disorder. 18.2% of patients without mTBI and 30% of patients in the mTBI group had a cluster B disorders including borderline personality disorder (BPD), narcissistic personality disorder (NPD), and histrionic personality disorder (HPD). 13.7% of patients without mTBI and 22.5% of patients with mTBI had BPD.						

¹ Structured Clinical Interview for DSM-IV Axis I Disorder² Health Related Quality of Life

Albicini and et al. (2015) (51)	Australia	103: 17 mild 2 moderate 1 severe	40% above 15 years 30% blow 15 years	Mild to severe	NA	Quantitative Cross-sectional	DSM OSU TBI-ID SF ¹ ASR ² ; Achenbach, Bernstein, & Dumenci	20.6 (SD=1.88) (18-25)
	Results	Twenty percent of TBI patients and 15% of non-TBI patients suffer from borderline or generalized anxiety disorder. Depressive symptoms were borderline or full-blown narcissism in 22% of patients with head injuries and 15% of patients without head injuries. Twenty-eight percent of people with head injury and 19% of people without head injury have an avoidant personality disorder that is either borderline or autochthonous.						
Norup, A., & Mortensen, E (2015) (21)	Denmark	22 TBI 22 SO	4 month	11.45±3.25 (5-15)	NA	Quantitative Cross-sectional	NEO-FFI Symptom Checklist-90-Revised HRQOL	SO: 49.7 (SD=12.8) TBI: 43.6 (SD=22.35)
	Results	59.1% of the patients were rated to have reliable personality change on at least one personality trait. Moreover, 27.3% showed significant changes in neuroticism, 22.7% showed changes in extraversion, openness, and agreeableness, and <5% showed changes in openness and agreeableness.						
Rodger A Weddell & Rodger L.L. Wood (2018) (52)	UK	71	57.9 (9-122)	GCS mean: 11 62 severe 8 moderate	Vehicle accident: 60.6% Fall: 14.1% Assault: 7%	Quantitative Cross-sectional	Frontal and Social Behavior Questionnaire Hospital Anxiety and Depression Scale (HADS) State-Trait Anger Expression Inventory (STAXI- II)	37.2 (19-63)
	Results	Respondents often experienced significant changes: none (4.5%), small (38.8%), large (41.8%), and complete (19.4%). Informant reports of PC were associated with lower emotion recognition and empathy, informant reports of sexual dysfunction symptoms, and higher informant emotional expression.						
Lange and et al. (2012) (53)	USA	25 uncomplicated mTBI 17 complicated TBI 42 moderate TBI	uncomplicated mTBI: 2.7 (1.9) complicated TBI: 2.1 (2.0) moderate TBI: 2.5 (1.9)	Mild to moderate	NA	Quantitative Cross-sectional	PAI	uncomplicated mTBI: 27.7 (6.9) complicated TBI: 30.9 (10.1) moderate TBI: 26.6 (7.9)
	Results	The uncomplicated mTBI group showed a higher prevalence of elevated anxiety-related disorder scale (33.3%) compared to the complicated mTBI group (5.9%). Furthermore, the uncomplicated mTBI group had a greater proportion of individuals with an elevated paranoia scale (41.7%) compared to the moderate TBI group (16.7%). Although not statistically significant, other notable findings included a slight or greater increase in aggression scale in the uncomplicated mTBI group (45.8%) compared to the complicated mTBI group (23.5%), with a difference of 22.3%. Additionally, there was a difference of 20.6% in the moderate antisocial trait scale between the severe TBI group (50.0%) and the complex mTBI group (29.4%).						
Hibbard and et al. (2000) (54)	USA	100 TBI	7.6 ±7.1 years (1-37)	NA	Motor vehicle accident: 62% Assault: 8% Pedestrian accident 8%	Quantitative Cross-sectional	NA	38.8±10.2
	Results	66% of TBI met criteria for one or more of PDs, 25% had one of PDs, and 41% had two or more of PDs. The most common personality disorders after head trauma are borderline 34%, obsessive-compulsive 27%, paranoid 26%, avoidant 26%, antisocial 21%, and narcissistic 14% and passive-aggressive 9%.						

¹The Ohio State University TBI Identification Method Short Form²Adult's Self Report

Obonsawin and et al. (2007) (55)	UK	184	6.6 (6.3) years (0.7-39.6)	Moderate: 17.9 % Severe: 82.1 %	NA	Quantitative Cross-sectional	Semi-Structured Interview	TBI: 35.2 (10.1) Non-TBI: 35.8 (12.2)
		Results	The prevalence of personality changes in people with mild TBI is reported to be only 3.5%, compared to 84% in people with severe TBI. Depending on the source, 64% to 82% of people in our sample showed personality changes (moderate or higher) including depressiveness (Depressiveness, Dissatisfaction, Loneliness, and Self-esteem, Changeability), lack of confidence (Confidence, Anxiety and Self-esteem) and emotional lability (Emotional Disinhibition, Quick Temper, Catastrophic reactions, Aggressive behavior, Changeability) on at least one of these factors. 63% and 85% of participants showed anxiety and depressive disorders					
Tate (2003) (56)	Australia	45 TBI	64.46 days (SD = 50.53 (14–224 days)	Severe	Road traffic accident: (n=21) 46% Assault: (n = 5) 11% Fall: (n = 1) 0.02%	Quantitative Follow-up	The Eysenck Personality Questionnaire —Revised (EPQ-R) The Current Behavior Scale (CBS)	26.82 years (SD=8.79)
		Results	Regarding the three primary personality dimensions (extraversion, neuroticism, and psychotics), TBI patients exhibited a higher degree of extraversion compared to their normative group (E at approximately the 64th percentile). Additionally, they displayed lower levels of psychopathology (P at the 38th percentile) and demonstrated greater emotional stability (N at the 26th percentile).					
Nelson and et al. (1998) (57)	USA	Clinical sample: 80 CHI ¹ Research sample: 48 CHI Control group: 129	NA	Research sample: M= 10.2 SD=4	Motor vehicle accident	Quantitative Cross-sectional	Neuropsychology Behavior and Affect Profile (NBAP)	Clinical sample: 33.68 (SD= 13.85) Research sample: 33.11 (SD=16.06) Control group: 37.93 (SD= 15.17)
		Results	Comparing the CHI group in the study with normal controls, the results showed significant differences in the apathy, inappropriateness, prognosis, and depression scales and participants in the clinical group scored significantly higher than subjects on apathy, futility, prognosis, and depression.					

Discussion

This study aimed to systematically review the existing research on PC in individuals with TBI at different severity levels, ranging from mild to severe. The review revealed that post-TBI personality disorders are common (47, 54), with more than 60 percent of participants in many studies reporting PC after injury (20, 37, 52). Although the frequency of PC in TBI patients ranged from 9.9% to 47.9%, varying from no change to complete personality change (38), a relationship between PC and TBI severity was not consistently reported (32, 37). In some studies, between 4.5% and 75% of patients exhibited no changes in their personality post-injury (34, 49, 52).

Contradictory findings regarding the effect of severity were noted. Depending on the methods used in different studies, personality, and behavioural changes due to mTBI ranged from 3.5% to 39.4% (32, 55), while medium to severe TBI showed a prevalence of 19.4% to 88% (52, 58), and severe TBI alone had a prevalence of 23.6% (39).

For all types of TBI, the prevalence ranged from 23.3% to 66% (46, 54). Notably, in nearly 60% of individuals with severe TBI, significant changes in at least one personality trait were observed before injury (20). Additionally, the mTBI group reported higher rates of personality and emotional pathology compared to the moderate and severe TBI groups (29, 59). Individuals with moderate to severe TBI exhibited substantial

¹ Closed Head Injury

emotional dysfunction and disrupted empathy (60), while patients with mild to moderate TBI were predominantly affected by psychological mechanisms related to anxiety, depression, or emotional distress (1). In other words, when brain systems involved in emotional, behavioural, and motivational regulation are damaged, significant PCs may occur in individuals with TBI (45). Furthermore, personality disorders are reported in 20% to over 50% of patients with TBI (20, 33, 49, 51, 52, 54). Specifically, approximately 25% of patients experienced a single personality disorder, while 41% experienced two or more personality disorders (54). Studies have demonstrated that more than two-thirds of individuals with TBI develop Axis 2 personality disorders after injury (54). The most prevalent disorders in this group include antisocial personality disorder, obsessive-compulsive disorder, avoidant personality disorder, paranoid personality disorder, schizoid personality disorder, borderline personality disorder, and narcissistic personality disorder (46, 49, 54, 61). In this context, apathy has been reported as the most common PC in patients with severe TBI. Previous studies have indicated that among a population of patients with severe TBI, 42.8%, 21.4%, 21.4%, and 14.4% were diagnosed with apathy, aggression, disinhibition, and a combined apathetic/aggressive profile, respectively, according to DSM-IV-TR criteria (39). Additionally, recent studies have demonstrated that 43% of patients with moderate to severe TBI exhibited unstable personality traits after injury (49). Furthermore, 29% of patients with TBI develop personality disorders after injury, with some cases showing a propensity for high-risk behaviours (35). Individuals with head injuries are at an increased risk of neurotic symptoms and experience more difficulties in emotion regulation, such as anger outbursts and aggression. On the other hand, individuals with TBI struggle more with understanding and managing negative emotions, such as anger, sadness, and fear, compared to positive emotions, like happiness. This emotional dysregulation may lead to heightened reactivity to negative emotional stimuli, manifesting verbally or behaviourally (62).

Post-TBI PCs reflect a variety of reciprocal factors, including physical effects such as neural network disruptions (63) and psychological and social

variables like adaptability (64, 65). These PCs manifest as a loss of self-confidence, attempts to confront cognitive and interpersonal failures in daily functioning, and struggles with negative emotions. Consequently, these findings highlight the recognition that people who have experienced TBI face emotional and interpersonal challenges in their relationships. They actively work to make up for and address the perceived losses they have encountered (54).

Compared to control groups, individuals with TBI exhibit higher levels of depression, helplessness, worthlessness, guilt, anger, anxiety, loneliness, and emptiness as common personality reactions and changes (66). Moreover, post-injury social and behavioral changes can be linked to cognitive injury due to both initial and secondary lesions after trauma, particularly those affecting executive functions (39). The pattern of brain network injuries can independently lead to PC and neuronal dysfunction (67). Recent studies have demonstrated a correlation between the lesion region and the presence of PC, confirming increased neuroticism in TBI patients with frontotemporal lesions (20). The incidence of aggressive personality changes has been associated with frontal lobe injury, post-injury amnesia, depressive disorders, and the level of adaptability after trauma (32), as well as with psychiatric disorders, particularly anxiety and mood disorders (especially depression) (58).

By way of explanation, posterior cingulate cortical lesions in abulia - a milder form of inactive mutism characterized by loss of initiative, spontaneity and motivation, slow thinking, and immediate emotional responses to external stimuli (68, 69) - are associated with apathy (70). Apathy is marked by an absence of feelings or emotions (69), reflecting the role of the cingulate cortex in initiating and sustaining purposeful mental behavior (71). Emphasis on the nosological condition, previous studies have differentiated apathy from other conditions, such as abulia and akinetic mutism, as well as mental states like hopelessness and demoralization. However, the role of emotion in apathy remains unclear, adding to the complexity of the nosological condition (72). Given that several regions associated with the amygdala are commonly involved in emotional processing and injury to the cingulate gyrus is common after TBI, the complexity of these

regions and their numerous projections contribute to the development of apathy in patients (71).

In addition, the majority of people with severe TBI experience long-term dysfunction that limits their participation in activities and affects their relationships (7). These patients often feel less able, dependent, and active (7), which impacts social interactions. The prevalence of aggression in previous studies ranges from 23.5% to 45.8% in individuals with mTBI (53), 27% in individuals with moderate to severe TBI (49), and 15% to 55% in individuals with severe TBI (27, 39, 73). EEG studies have shown a positive relationship between frontal lobe disorders and aggression (74, 75). Furthermore, MRI studies have reported a positive relationship between aggression and increased connectivity between the right hippocampus and middle cingulate cortex (76). However, it remains uncertain whether aggression increases the risk of mTBI or if a history of mTBI alters brain structures, leading to increased aggression (77).

The aforementioned findings can be elucidated by examining the relationship between brain regions affected by TBI and their impact on the emotion regulation system (78). MRI studies on individuals with TBI and associated internal problems have identified critical regions such as the orbitofrontal cortex, the thalamus, the temporal lobes, the amygdala, the frontal gyri, and the hippocampus (78-79-80). Specifically, frontal injury or dysfunction in posterior cingulate networks is linked to disruptions in thalamic functional connectivity and the mesencephalic-pontine dorsal tegmentum, which is related to the arousal system (81). Thus, these areas are crucial for regulating affect and maintaining appropriate emotional states (82). Disruptions in these regions in individuals with TBI lead to significant emotional and personality disorders (78). Moreover, since the frontal cortex regulates emotional activities and automatic responses to sensory and limbic information involved in emotional expression (58), injury to the frontal lobe and serotonergic absorption pathways contribute to the pathology of aggressive behaviours after TBI.

Consequently, disruptions in emotional and behavioural regulation, diminished emotions and energy (indicative of disinterestedness), distress,

anxiety, and executive dysfunction are common outcomes of frontal lobe injury (83). Additionally, disinhibition movement from inhibition to emotional overreaction characterizes post-TBI PC (67). Post-TBI performance deficits, often associated with changes in the frontal cortex, hippocampus, and corpus striatum, may indicate perceived inadaptability and depression; however, these correlations are not necessarily causal. In other words, emotional distress arises in response to numerous observable psychosocial effects of TBI, including PC, and can be mitigated through cognitive-behavioural interventions (38).

PC is significantly associated with deficits in critical neuropsychological domains, including mental function, processing speed, divided attention, verbal memory, working memory, verbal fluency, and executive function (67). It implies difficulties in task performance, purposeful duties, and adaptation to new challenges. Consequently, dysfunctions in working memory, planning, and problem-solving abilities may result in the selection of more aggressive responses. Additionally, post-injury amnesia, manifesting as secondary delirium in patients with TBI, can lead to extreme behaviours such as aggression, akathisia, disinhibition, and emotional lability (32). Moreover, individuals with higher cognitive function after TBI may have a greater awareness of their deficiencies, heightening the risk of anxiety or weak mood (84). Awareness of cognitive failures may also exacerbate perceived deficiencies in PC among TBI patients (38), and those who experience more rapid memory recovery after injury have a reduced likelihood of long-term recovery from TBI-induced PC (39).

However, PC is not solely due to the neuropathological consequences of TBI (44). The variability in assessment methods, lesion scope, and disease severity complicates comparisons of PC prevalence across different studies (55). In this way, Individuals with certain pre-existing personality traits may encounter more significant problems post-brain injury (54). The prevalence of PCs ranges from 10% to 70%, depending on TBI severity and the time elapsed since injury (85). Therefore, research has indicated that individuals with mTBI exhibit higher rates of personality and emotional changes compared to those with moderate and severe TBI (29). This discrepancy can be attributed to factors such as the cause of referral, testing time, and the

severity of brain injury, all of which may influence post-injury emotional outcomes. Furthermore, if an individual suffers a brain injury and subsequently experiences chronic emotional problems, they may tend to retrospectively assess their pre-injury emotional functioning more favourably.

According to previous studies, the high frequency of reported PC and the myriad of recognized personality disorders in individuals with TBI indicate that PC does not constitute a distinct personality syndrome after TBI. Instead, it is specific to each individual and significantly impacts their quality of life and daily functioning. The durability of these changes remains uncertain, raising the question of whether patients will return to pre-injury functioning. Consequently, longitudinal studies are recommended to follow TBI patients experiencing PC. Information regarding family, interpersonal, and socioeconomic environments, as well as significant life events (both past and present), may enhance understanding of the causes and conditions of head injuries and related environmental factors (86). Additionally, considering the significant advancements in treatment methods and diagnosis of head injuries in recent decades, the lack of precise information about the time of injury may contribute to uncertainty (35).

Conclusion

This systematic review, therefore, underlines the significant prevalence and complexity of personality changes among individuals who have suffered from traumatic brain injury, regardless of the severity. The findings reveal that a considerable proportion of patients suffering from TBI experience personality disorders, with the prevalence rates differing significantly depending on the severity of the injury and the characteristics of the individual. Notably, challenges such as emotional dysregulation, apathy, and aggression are common, highlighting the complex interplay between brain injury and personality changes. The review, therefore, illustrates that personality changes are not solely the result of neurological damage but are influenced by various factors such as psychological, social, and individual traits. As previously discussed, ongoing studies aim to address the changes and outcomes resulting from TBI

and to develop new, more effective treatment methods for this population. It is crucial to recognize and explain post-TBI PCs, their outcomes, phenomenology, symptoms, and characteristics of deficits for accurate diagnosis and the early and effective implementation of treatment interventions. Therefore, a comprehensive rehabilitation program tailored to each patient's needs and focused on addressing skill deficits and subsequent behaviour and personality changes necessitates continuous collaboration among healthcare experts and providers.

Conflict of Interest

The authors declare no conflict of interest.

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