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Review Paper

Emotion Dysregulation Following Traumatic Brain Injury: A Systematic Review

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ABSTRACT

Background and Aim: Emotion dysregulation (ED) after traumatic brain injury (TBI) can exacerbate a wide range of symptoms, including problems in restraining emotions and behaviors, executive function disorders, and diminished emotional awareness and expression. This study aims to systematically review these studies on emotion dysregulation (ED) in people with TBI.

Methods and Materials/Patients: PubMed, Web of Science, Scopus, as well as Google Scholar, were systematically searched for required articles published between 1997 and 2023. The eligibility of identified literature was determined by screening the titles and abstracts by two autonomous researchers, denoted as the first author and the second author. Only those studies that reported either emotional regulation or expressive suppression in their findings of TBI adults were included in this review. The abstract and full text of search results were screened by Rayyan QCRI (Qatar Computing Research Institute) intelligent systematic review. Subsequently, the two researchers independently assessed the full-text versions of the residual articles to determine their admissibility. Disputes at each stage were amicably resolved through discourse and consultation.

Results: Of the 773 articles identified, 361 studies remained after removing duplicate studies. A final 58 studies were retrieved for full-text screening based on inclusion criteria. So that after the renewed screening, 34 studies were included in this review, which indicated the existence of emotional problems in patients with TBI in all severities.

Conclusion: Even though numerous effective factors either physical or psychological aspects made brain injuries more complicated, long-term outcomes associated with post-injury emotional and mental distress and dysregulation have rarely been analyzed in terms of TBI treatment. Hence, by considering medical and clinical psychology care, a more comprehensive approach can be adopted to treat people with TBI and improve their quality of life.

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Highlights

• If people with traumatic brain injury (TBI) dedicate more mental and physiological resources to preserve stable cognitive functioning over time, it can lead to persistent problems associated with mood disorders and emotion dysregulation (ED) following their injury.

• Different cortical and subcortical regions, including the amygdala and hippocampus, are involved in emotion regulation processes and it can lead to problems in the adaptive response to stress by a disruption in regulating the hypothalamic-pituitary-adrenal axis.

• In people with TBI, due to a disruption in higher-level cognitive functions, such as loss of concentration in purposeful activities and problem-solving, more anger expression or uncontrolled emotional events are observed.

Plain Language Summary

Above 60 million cases of traumatic brain injury (TBI) worldwide result in lacking emotional response to trauma, distress caused by physical and psychological symptoms, and even physical and movement disabilities. Even though neuroimaging is developed, in some cases, it does not show traumatic anomalies. Therefore, the risks of psychological disorders increase substantially after TBI, so disturbances in regulation, control, assessment, expression, modification, and true emotional responses are among the most common and disabling outcomes of TBI. In addition, not only does emotional dysregulation severely affect a person's capacity to encounter daily occasions but also TBI treatment and recovery are impressed by emotional disturbances and exacerbate the symptoms regrettably. Hence, perception of post-TBI emotional dysregulation and its consequences is necessary to treat people with TBI and improve their life quality.

1. Introduction

Traumatic brain injury (TBI), known as a "silent epidemic" [1] with an approximate annual incidence rate of 69 million worldwide cases [2], is presumed to be one of the three major causes of injury-related deaths and disabilities by 2030 [3]. According to the Centers for Disease Control and Prevention (CDC), TBI is caused by a bump, blow, or jolt to the head, contusion, or head-penetrating injury, disrupting the normal structure and function of the brain temporarily or permanently [4, 5]. In other words, TBI includes a heterogeneous group of pathologies with various onset mechanisms leading to different adverse outcomes [6] with acute (days to weeks) and chronic (months to years) symptoms [7]. In addition to physical complications caused by TBI, serious outcomes associated with alteration in brain function are disruptions in cognitive, emotional, and behavioral functions needed in both personal life and social life [8]. Accordingly, patients with TBI impose a heavy burden on the healthcare system and economy of societies worldwide [9].

Although acute symptoms are presumed to be caused by a brain injury, computerized tomography (CT) scan or magnetic resonance imaging (MRI) do not show traumatic anomalies in some cases. Even if the anomalies are identified, they present a weak correlation with the intensity of persistent symptoms [10]. Nevertheless, a significant correlation is observed between post-injury outcomes caused by TBI (e.g. neuronal death, white matter damage, and neuroinflammation), emotional response to trauma, and distress caused by physical and psychological symptoms [11]. Regardless of a prior psychological record, the risks of psychological disorders substantially increase after TBI. These disorders, psychological conditions, and related cognitive, behavioral, and emotional outcomes are probably caused by acute and chronic emotional dysregulation resulting from post-traumatic physical or emotional insults [11].

Emotion regulation refers to complex internal and external neuropsychological processes. It is the ability to control, assess, express, and modify affects and emotional responses according to their particular characteristics and time. Hence, to achieve goals, emotion regulation is manifested in individual behavior [12–16]. Modifying the expression of affects and emotions, known as the key element of emotion regulation, is controlled by the prefrontal cortex, which is the main region for emotional cognitive control [17]. Anatomically, forceps minor, uncinate fasciculus, and cingulum bundle

are major pathways for white matter, connecting prefrontal and limbic regions in the emotion regulation circuit. Due to their locations at the front of the skull, they are vulnerable to brain injuries [18-20]. Thus, since brain injuries can disrupt emotions leading to persistent symptoms [21], emotional dysregulation is one of the most common and disabling outcomes of TBI [22].

Emotion dysregulation (ED) can exacerbate a wide range of symptoms, including problems in restraining emotions and behaviors (e.g. aggression, inappropriate social behavior, irritability, and impulsivity), executive function disorders (e.g. in problem-solving or purposeful behavior), and diminished emotional awareness and expression (e.g. passivity and indifference) [23, 24]. In other words, the inability to decode feelings in others not only prevents socially-adjusted responses in people with TBI but also disrupts recognizing one's emotional states as the first stage of appropriate and optimal regulation of emotions [22]. Accordingly, ED can challenge the ability to cope with everyday situations, intensifying disrupted cognitive processes [25]. Moreover, post-TBI recovery is highly affected by a person's capacity to regulate negative emotions, something which determines the ability to deal with injury consequences (e.g. symptoms or temporary changes in daily performance) [17–19].

With the rising occurrence and prevalence of TBI, healthcare providers increasingly encounter people with TBI following their injury [26]. Despite its clinical importance, many studies have addressed TBI management in medical fields other than psychiatry [27]. Researchers have not sufficiently emphasized the outcomes of ED in people with TBI with limited attention to post-TBI emotional disorders. Thus, this review was performed to analyze the perception of post-TBI emotional dysregulation.

2. Methods and Materials/Patients

The systematic review was conducted according to a predetermined protocol and established guidelines (preferred reporting items for systematic reviews and meta-analyses) [28].

Eligibility criteria

Studies were included if, articles were published in the English language, reported as a completed study, were published from 1997 onward to the first of January 2023, participants had at least 16 years of age (this was done to avoid confounds associated with the development of emotion regulation), and evidence of TBI were determined using one or more of the following methods including Glasgow Coma Scale (GCS), reported the loss of consciousness or evidence of post-traumatic amnesia, clinical or neuroimaging diagnosis.

Studies or papers that did not meet the above criteria were excluded. No geographical limitations were applied. Moreover, study protocols, literature reviews, methodological papers, or conference abstracts were excluded (after conducting additional searches to ensure that full papers had not been subsequently published). Articles not measuring aspects of emotional expression or regulation and longitudinal studies where the sample consisted of participants who were children at the time of TBI were not eligible to enter the study.

Search strategy

The primary search was conducted in December 2022 and an updated search was conducted on February 1, 2023. Titles and abstracts were screened using PubMed, Web of Science, Scopus as well as Google Scholar to comprise two concepts of TBI and emotion regulation. Moreover, a manual search of the articles or reference lists was performed to identify either keywords or keyword combinations. The following keywords or MeSH terms (medical subject headings) were used to search the database, emotional regulation, emotions, brain injuries, and TBI. Moreover, the subject-specific keywords [TBI OR traumatic brain injury OR head trauma OR brain trauma OR contusion OR brain injuries] AND [emotional affect OR emotion regulation, OR positive affect OR negative affect or positive mood or negative mood OR emotional expression OR emotional problem OR emotional dysregulation OR emotions] were combined separately to help identify relevant papers.

The completed search results were downloaded into Endnote X9 (Clarivate, USA) for citation management and deduplication. Screening was done in a web-based screening program, called Rayyan QCRI intelligent systematic review [29]. Rayyan (Rayyan Systems, Inc., USA) allows abstract and full-text screening of studies depending on custom inclusion and exclusion criteria. Duplicate reports were initially eliminated; then, studies were screened based on title and abstract only using the inclusion/exclusion criteria outlined in the previous section. Moreover, studies that were borderline for inclusion were more thoroughly screened by examining their full text. In addition, the reference lists of the studies were checked for any related studies that were not picked up by the search. In the initial step, both review-

Table 1. The information extraction strategy from each paper

Extracted Information	Explanation
Citation information of the article	Author's name/s and the year of publication
Country or region	Which research was conducted there
Number of participants	Participants in each group of the study
Mean of age	For each group separately
The severity of TBI or mean of GCS, if reported	It was not mean TBI severity reported in the study, GCS or PTA were used to calculate the mean severity by the reviewers.
TBI-caused category if reported	The three reasons reported in the study.
Emotional dysregulation measure	The measures were used to determine the level of emotional dysregulation in the participants.
The key result of each study	It can include the comparison between the result of groups or the main result shown in the study.

Abbreviations: TBI: Traumatic brain injury; GCS: Glasgow Coma scale; PTA: Post-traumatic amnesia.

ers screened all references by title and abstract and then retained suitable articles. Then the full-text manuscripts of papers that remained after abstract screening were assessed for eligibility by the reviewers. While the final articles were identified for inclusion, the extraction of relevant data was conducted by both reviewers autonomously. If any discrepancies existed at each section of the review proceeding, they were resolved through consensus.

Data extraction

Table 1 presents the information extracted from each paper.

3. Results

A total of 773 articles were identified, 305 from Google Scholar, 193 from PubMed, 171 from Web of Science, and 88 from Scopus. After removing the duplicate studies, 361 studies remained and the abstracts were carefully screened and evaluated. Of these, 303 were excluded (16 were non-English articles; 88 included another type of brain injury; 145 did not measure emotional regulation; 54 were conference abstracts) (Figure 1).

A final 58 studies were retrieved for full-text screening. Of these, 24 were excluded because, after further review, it was determined that they did not include or report emotion regulation assessment and that the par-

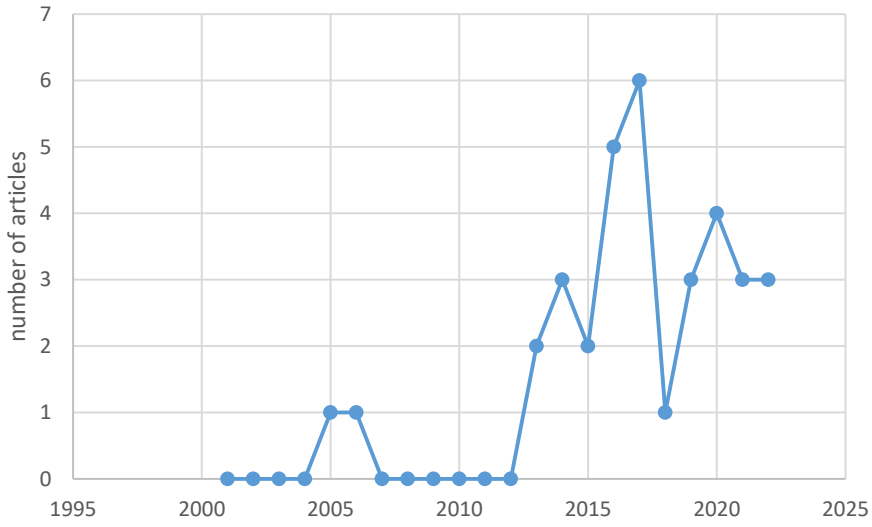

Figure 2. The number of articles about TBI and emotional problems in different years

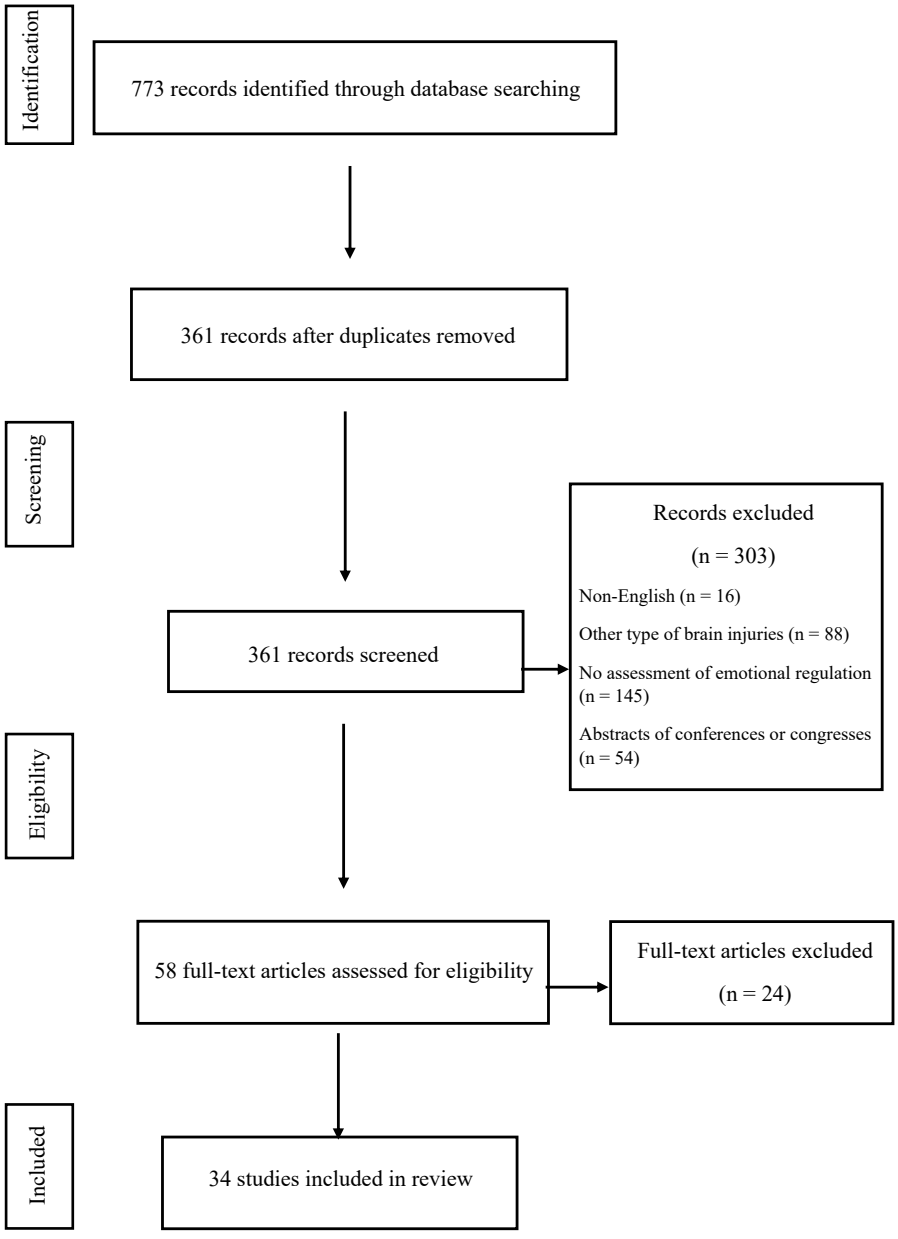

Figure 1. Flowchart of study selection

ticipants did not have traumatic brain injuries. Finally, 34 studies were included in this review.

Table 2 presents the main features of the studies included in the systematic review. Moreover, the pooled sample size was 2676, and the individual sample size varied from 1 to 636 in different studies. In addition, 23 studies (93%) were published between 2013 and 2023. Another 2 studies (7%) were published before 2010 (Figure 2). The countries in which the studies were conducted were geographically dispersed, 15 studies were conducted in the United States (41%) and 1 study was conducted in Europe, specifically 1 in the United Kingdom (2%), 4 in the Netherlands (11%), 2 in Norway (5%), 1 in Finland (2%), and 1 in Switzerland (2%). Five studies were conducted in Asia, 3 in Iran (8%), 1 in Korea (2%), 1 in India (2%), and 5 in Australia (14%). Moreover, TBI severity prevalence in the studies used in our research is reported as follows, 8 studies included a mixed sample of spectrum of TBI (mild, moderate, and severe) (23%). Four studies included severe types of traumatic brain injuries (10%). Three studies included mild types of traumatic brain injuries (8%). Seven studies included moderate and severe types of traumatic brain injuries (20%). One study included moderate and mild types of traumatic brain injuries (2%).

Table 2. Summarizing the main features of the studies

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Aboulafia-Brakha et al. (2016) [30]	Switzerland	Quantitative	TBI: 17 Control: 12	Controls: 33.4±8.5 TBI: 37.4±12.6	All (GCS mean: 7.8±4.3) Severe: 12 Moderate: 3 Mild: 5	Motor vehicle accidents (65%)	- Self-report questionnaires to assess anger expression and regulation - Anger regulation task + SCL+STAXI-State (15 items) - Aggression questionnaire (AQ-12) - The Multidimensional anger reaction scale (MARS) (28-item)	Participants with TBI reported that their current level of anger and aggression is much higher than before the accident. TBI survivors with anger problems show greater increases in sympathetic arousal during spontaneous anger recalls. TBI participants demonstrate similar modulation of perceived feelings of anger regulation strategies, including an adaptive strategy. The results have shown that not only a possible disruption exists in sympathetic activity following head injury that may underlie problems with anger regulation in this population but also it emphasizes promoting awareness and managing physical activity, as well as encouraging the use of cognitive restructuring strategies.
Ashworth et al. (2015) [31]	United Kingdom	Quantitative	1	20	Severe	Road traffic accident (RTA)	- Beck anxiety inventory (BAI) - Beck depression inventory 2nd edition (BDI-II) - Robson self-concept questionnaire (SCQ) - State trait anger expression inventory (STAXI)	This case illustrates the successful application of the CFT approach using CMT in a person with high levels of anxiety, depression, anger, and low self-esteem, and the complex cognitive consequences of post-ABI in the context of a holistic neuropsychological rehabilitation program.
Dethier et al. (2013) [32]	Australia	Quantitative	TBI: 24 Control: 28	Controls: 41.5 TBI: 46.54	Severe	NR	- The depression, anxiety, and stress scale (DASS-21) - Body and facial feedback task	Results showed that both control participants and TBI participants were affected by expressing happiness and manipulating attitudes. The control participants were more affected by the sad and angry face/manipulative posture than the TBI participants. A non-significant tendency for control participants to be more anxious about negative statements/attitudes than about positive ones. For TBI participants there is no difference between the two groups. Control participants felt more disgust during anger than during other facial/postural manipulations. No significant differences were observed for TBI participants or between the two groups. The reported problems in regulating negative emotions, particularly anger, after TBI may be due in part to the difficulties that people with TBI have in properly identifying their emotions. Recovering from deficits in emotion regulation after TBI may require addressing the disconnect between emotional behavior and emotional awareness to consciously control emotional behavior.

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Campbell et al. (2021) [33]	United States	Quantitative	TBI: 79 veterans Control: 17	Controls: 29.59 TBI: 35.92	NR	NR	- PERT96 face collection - Patient health questionnaire-9 (PHQ)	Veterans with post-traumatic stress disorder (PTSD) and traumatic brain injury (TBI) were more responsive to background information or distractions.
Fisher et al. (2014) [34]	Australia	Quantitative	TBI:19 Control: 15	Controls: 43.95 TBI: 44.89	Severe	MVA-Pass 57.9% Fall 26.3% assault 15.8%	- Face stimuli (NimStim set of Facial expressions) - EEG	Stimulus control language (SCL) for the TBI group was lower than controls for all conditions TBI participants showed less decrease in alpha power between baseline and face viewing conditions compared to the control group No difference was observed in alpha power between TBI participants relative to controls, for the evaluated baseline condition
Sultana et al. (2022) [35]	Australia	Quantitative	32 veterans with TBI (split up into active (n=17) sham (n=15) groups randomized mild and moderate TBI)	20 to 69 year	Mild Moderate	NR	Veterans RAND 36 item health survey (VR-36)	The difference between the emotional health scores of the active group before and after rTMS was statistically significant and showed an improvement in emotional health after rTMS, while it was not statistically significant in the sham group. The main effect of rTMS is to reduce emotional disturbances and therefore may improve cognitive and executive functions. Our results implicate impaired connectivity from the dorsal anterior cingulate cortex to the left anterior insula and medial prefrontal cortex after rTMS as a potential neural mechanism underlying improved emotional health.
Stubberud et al. (2020) [36]	Norway	Quantitative	70 ABI (TBI:45 Stroke:15 Tumor:6 Anoxic:2 Other:2)	43	NR	NR	Brain injury trust regulation of emotions questionnaire (BREQ)	Analyzes showed a significant association between self-reported emotion regulation scores (BREQ) and symptoms of anxiety and depression.
Shields et al. (2016) [37]	Australia	Quantitative	50	43.2	Mean GCS:10.32	Traffic-related %48 Fall %24 Assault %10 Sporting injury %16	- Appraisal of threat and avoidance questionnaire (ATAQ) - Head injury semantic differential scale (HISD) - Penn state worry questionnaire (PSWQ) - Depression anxiety and stress scales 21 (DASS 21) -BSI-18 (derived from the Symptom Checklist-90) - Difficulties in emotion regulation scale (DERS)	The emotion dysregulation factor explained a significant and unique variability in the magnitude of depression, anxiety, and global distress. Results indicate the need for interventions targeting difficulties in identifying and regulating emotions after CBT to facilitate emotional adjustment.

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Choi, Ho Jang (2020) [38]	Korea	Quantitative	1 m	51	Severe	Car accident	- Diffusion tensor tractographies (DTTs) - Beck depression inventory-II	Demonstrated the degeneration of core neural circuits responsible for emotion regulation in a patient with delayed behavioral changes after TBI. Results suggest that assessment of these neural tracts followed by DTT is helpful when a patient on TBI has delayed-onset behavior problems
Dretsch et al. (2017) [39]	United States	Quantitative	Chronic mTBI:37 Control:35	mTBI:32.1 Control: 30.9	NR	NR	- Emotional regulation task - Brief traumatic brain injury screen - PTSD checklist-5 (PCL) - Neurobehavioral symptom inventory - Life events checklist -Combat exposure scale - Childhood environment - Zung depression scale - Zung anxiety scale - Epworth sleepiness scale - Automated neuropsychological assessment metrics (ANAM) version 4	Significant differences were observed between the groups, with the mTBI group reporting higher scores for alcohol use, post-concussive symptoms, daytime sleepiness, sleep quality, traumatic life events, PTSD symptoms, and anxiety and depression symptoms. Hyperactivation of neural regions in the mTBI group during the elevated state may reflect attention to negative contextual stimuli and or poor strategy, which may lead to the misallocation of emotion regulation resources.
Novakovic-Agopian et al. (2017) [40]	United state	Quantitative	24	41.13	Mild:13 Moderate:5 Severe:6	NR	- Mayo-Portland adaptability inventory (MPAI-4) - Goal processing questionnaire (GPQ) - Beck depression inventory-II (BDI-II) - PTSD checklist, Military version (PCLM) - Profile of mood states (POMS)	The results suggest that significant and long-term improvement in cognition, as well as emotion regulation and daily functioning in people with chronic CBT and cognitive impairment, is possible after executive function training.

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Fishbein et al. (2014) [41]	United state	Quantitative	636	35.5	NR	NR	- Buss Perry aggression questionnaire (BPAQ) - 12-item short form (BPAQ-SF) - Abbreviated dysregulation inventory (ADI)	We predicted that the mTBI group would perform better on lower scores on aggression, drug use severity, and older age at the onset of drug use as moderate TBI by monitoring alcohol consumption in the year prior to imprisonment. The result suggests that head trauma may be an indicator of emotional dysregulation, which is significantly associated with total aggression The result shows that younger current age and younger age of first drug use and head trauma before or after age 13 predicted higher overall aggression compared to inmates who never reported TBI (drug use severity was not significantly associated and therefore it was not included).
Grimm et al. (2017) [42]	United state	Multimethod Quantitative	3	44.33	NR	NR	- Emotion regulation scale (DERS)- 36 item - 18 question face-to-face semi-structured interview format - Registered yoga therapist (RYT)	The data provide a preliminary case study of an individualized yoga intervention and support further research on yoga as a therapeutic intervention after TBI.
Killgore et al. (2016) [43]	United state	Quantitative	mTBI: 26 Control: 12	mTBI: 23.38 Control: 25.00	NR	NR	Personality assessment inventory (PAI)	These results support existing research on compensatory brain mechanisms after TBI, suggesting that TBI may be followed over time by increased compensatory remodeling of various cortical regions, particularly those involved in emotion regulation, which in turn, it reduces distraction during motor activities. The ventromedial prefrontal cortex is particularly important in emotion processing and regulation, and gray matter volume in this region was directly associated with decreases in anxiety-related clinical symptoms in this study.
Westerhof-Evers et al. (2019) [44]	Netherland	Quantitative	59	NR	Moderate Severe	NR	Treatment of social cognition and emotion regulation: - Session1: Psychoeducation - Session2-6: Emotion perception - Session7-11: Perspective taking and the- ory of mind - Session12-20: Social behavior	The broad-spectrum treatment ingredients may be also useful for other types of patients with acquired brain injury or traumatic brain injury in the subacute and chronic phase, provided that they have deficits in social cognition and associated behavioral problems.

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Horn et al. (2021) [21]	Netherland	Quantitative	PTS+: 33 PTS−: 20 CT+: 14 (with 5/14 moderate TBI) HC: 20	CT+: 44.5 PTS+: 33 PTS-: 34 HC: 29.5	CT+: Mild PTS+: Mild PTS-: Mild	NR	NR	Prevalence measurements in the uncomplicated mTBI group showed no significant influence on the number of symptoms or the presence/absence of lesions on conventional MRI or the interaction between the two variables.
Finnanger et al. (2015) [45]	Norway	Quantitative	TBI: 67 Control: 72	29	Moderate Severe	Traffic accidents 33 (49%) Fall 27 (40%) Ski accident 2 (3%)	- Self-reported executive function BRIEF-A - Self-reported emotional and behavioral problems	Subjects with moderate and severe TBI reported significantly greater difficulties in aspects of executive functioning related to attentional control, working memory, and emotional regulation, as well as emotional and behavioral problems related to symptoms of depression, anxiety, and aggressive behavior 2-5 years after injury compared to healthy individuals in the control group. The presence of traumatic axonal injury on early MRI and self-reported depressive symptoms within the first year after injury was strong predictors of later self-reported executive, emotional, and behavioral problems.
Horn et al. (2016) [46]	Netherland	Quantitative	mTBI: PTC-present:34 PTC-absent: 20 HC:20	mTBI: PTC-present: 35 PTC-absent: 34 HC:30	Mild	Accident: PTC+: 50% PTC-: 50% Fall: PTC+: 41% PTC-:49% Sports: PTC+: 3% PTC-:0%	- 19-item post-traumatic questionnaire - Rivermead post-concussion symptoms questionnaire (RPQ) - Hospital anxiety and depression scale (HADS)	The interaction between executive networks and the salience network is closely related to anxiety and depression, underscoring the putative role of these networks in post-mTBI emotion regulation.
Marsh and D A. Kersel (2006) [47]	Australia	Quantitative	62	TBI: 28 Caregivers: 44	Severe: 81% Moderate: 15% Mild: 5%	Road traffic crash: 76% Fall: 10% Assault: 8%	-Head injury behavior rating scale (HIBS)	The correlation between patient groups and reference persons for the sum of the emotion regulation subscale was statistically significant and most (above 80%) of these significant differences related to elements of behavioral regulation, not emotion regulation.
Novakovic-Agopian et al. (2019) [48]	United state	Quantitative	BHE: 19 GOALS: 21	BHE: 47.53 GOALS: 42.1	mTBI	NR	- Mayo-Portland adaptability inventory (MPAI-4) - Goal processing questionnaire (GPQ) - Profile of mood states (POMS) - Beck depression inventory-II (BDI-PTSD checklist, military version (PCL-M)	Attentional self-regulation training applied to participant-defined goals may improve either cognitive function or other areas, such as emotional regulation and functional performance in veterans co-existing with PTSD and mTBI. Goal-oriented attentional self-regulation training, participants reported significant improvement from baseline on key outcome measures: Overall attention/executive functioning Psychopsychological fitness syndrome and general mood disorders-POMS self-assessment of emotion regulation, reduction of PTSD symptoms and improved performance on complex functional tasks: Learning and storing GPS.

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Shafiei et al. (2018) [49]	Iran	Quantitative	TBI: 72 Control: 72	TBI: 15-30: 51.4% 31-45: 34.7% 46-55: 13.9% Control: 15-30: 44.4% 31-45: 33.3% 46-55: 22.2%	NR	NR	Difficulties in emotion regulation scale (DERS) Persian version by Mirzaei)	The result not only showed difficulties in emotion regulation in the TBI group but no significant differences were observed between the mean values of the normal controls. Results showed that trauma, age, family history of mental disorders, and financial status can predict emotional regulation.
Nemattavousi and Soltaninia (2020) [50]	Iran	Quantitative	60	18-45	NR	NR	- Acceptance and action questionaries-2 (AAQ-2) - Toronto alexithymia scale-20 (TAS-20) - Difficulties in emotion regulation scale (DERS)	The significant relationship between alexithymia and emotion regulation and experience avoidance plays a partial interface role in the relationship between alexithymia and difficulties in emotion regulation.
Sun et al. (2020) [51]	United States	Quantitative	93 US military veterans	34.35	NR	NR	- Minnesota blast exposure screening tool (MN-BEST) - Clinician administered PTSD scale for DSM-IV (CAPS) - Minnesota multiphasic personality inventory-2–restructured form (MMPI-2-RF) - N-back task stimuli	Cognitive load increased the dorsolateral prefrontal cortex activity and decreased activity in emotionally sensitive brain regions. The result showed that high emotional/internal dysfunction (EID), particularly low positive emotionality (RC2), explains PTSD symptomatology-related changes in the bilateral amygdala under increased cognitive load.
Seyed Ebrahimi (2022) [52]	Iran	Quantitative	Tbi-borderline: 30 Control: 30	Tbi-borderline: 35.48 Control: 36.14	NR	NR	- Garnfsky emotion regulation questionnaire (2001) - Defense mechanism Andrews questionnaire (1998)	In the pre-test period, not much difference was observed between the control and experimental group means in terms of emotion regulation, but as you can see, a clear difference was observed between the mean scores in the post-test period, and that post-test was higher after positive thinking and mindfulness training; therefore training positive thinking and mindfulness improves the level of emotion regulation and improves defense mechanisms in the TBI group compared to the control group.
Tsaousides et al. (2014) [53]	United States	Quantitative	7	NR	All	NR	- Difficulties in emotion regulation scale (DERS) - Brain injury rehabilitation trust regulation of emotions questionnaire (BREQ)	The exceptional adherence and self-reported satisfaction suggest that this treatment option can be a viable alternative to improve access to healthcare in this population. The results of the study allowed the development of a large clinical trial to evaluate the effectiveness of the treatment.

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Siponkoski et al. (2021) [54]	Finland	Quantitative	TBI: AB:14 BA:6 Caregiver: AB:10 BA:5	AB:41.6 BA: 41.8	Moderate Severe	Traffic-related fall	- BRIEF - BDI-II	Qualitative feedback showed that many people with TBI experienced a positive impact on their emotional well-being on an individual level and also cognitive benefits were scored much lower than the general and emotional domains.
Donnelly et al. (2022) [55]	United States	Quantitative	TBI: 53 Caregiver: 15	18-34: 43.4% 35-54: 32.1% 55-70%	All	NR	- Quality of life after brain injury overall scale (QOLIBRI-OS) - NIH TBI/Neuro-QOL resilience - Emotional/ behavioral dysregulation	Significant improvements were seen in QOLIBRI-OS, resilience, cognition, and emotional/behavioral dysregulation in TBI survivors. Content analysis revealed community connection, reframing the TBI experience, self-regulation, and self-care motivations.
Neumann et al. (2017) [56]	India	Quantitative	17	46.12	Moderate Severe	Motor vehicle accident: 44% Fall: 32% Assault: 8%	- The levels of emotional awareness scale (LEAS) - State trait anxiety inventory - Patient health questionnaire-9 (PHQ-9) - State-trait anger expression inventory (STAXI-2) -Positive and negative affect scale - Difficulty with emotion regulation scale (DERS) -Satisfaction questionnaires	Post-treatment changes showed moderate to large effect sizes with improvements in alexithymia, emotional awareness, anxiety, positive affect, and overall emotion regulation. In addition, some changes persisted for several months after treatment.
Tsaousideset al. (2017) [24]	United States	Quantitative	81	47.08	All	NR	- Difficulties in emotion regulation scale - The positive affect negative affect schedule (PANAS) - Satisfaction with life scale (SWLS) - Problem solving inventory (PSI) - Social problem-solving inventory-revised: Short form (SPSI-R:S) - Dysexecutive questionnaire (DEX)	Significant changes with large effect sizes for DERS were detected during the 12-week follow-up. Online EmReg appears to be a promising group intervention to improve emotional regulation after TBI. Multiple benefits were observed about improved emotional regulation scores, subjective well-being, and problem-solving.

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Elbogen et al. (2019) [57]	United States	Quantitative	Tbi: 112 Control: 112	Tbi: 38.77 Control: 36.25	Moderate Severe	NR	- Dimensions of anger reactions (DAR) - Anger disposition directed toward other people designed for and validated in combat veterans with PTSD	Over six months, not only did veterans randomized to CALM reported a 25% decrease in anger compared to an 8% reduction in the control but also 26% fewer maladaptive interpersonal behaviors (eg, aggression) compared to a 6% reduction in the control; so that CALM can be effective for reducing emotional dysregulation in veterans with TBI and PTSD.
Westerhof-Evers et al. (2017) [58]	Netherland	Quantitative	TBI:59 Control: 88	TBI: 43.2 Control: 43.1	Moderate Severe	NR	- T-ScEmo - Dysexecutive questionnaires social scales (DEX-Soc-self, DEX-Soc-proxy) - Brock's adaptive functioning-social monitoring scale (BAFQ-SM-self, BAFQ-SM-proxy) - Relationship quality scale (RQS)	Compared to the Cogniplus group, the T-ScEmo group had significant improvement in facial affect recognition, and theory of mind, indirectly assessed empathic behavior, social participation, and treatment goal achievement, which persisted up to 5 months after treatment became. During follow-up, the T-ScEmo group also reported improved quality of life, and their life partners rated relationship quality as superior compared to the Cogniplus group.
Beresford et al. (2005) [59]	United States	Quantitative	18	45.4	NR	Motor vehicle	- Psychiatric diagnosis	Above 80% of participants have shown improvement in their affective and anxiety symptoms during treatment.
Azulay and T Mott (2016) [60]	United States	Quantitative	25 Post stroke: 10 TBI: 5 Autoimmune: 7 Post injury period greater than 10mo.	<12: 2 (4.5%) 12-16: 20 (81.9%) >16: 3 (13.6%)	Moderate Severe	NR	- Difficulties in emotion regulation scale (DERS) - The Freiberg mindfulness inventory - Perceived quality of life (PQOL) - Neurobehavioral symptom inventory (NSI) - Perceived self-efficacy (PSE) - Social problem-solving inventory-Revised short form SPSIR	Emotion regulation may be associated with treatment aimed at improving awareness (not locally), self-confidence, self-acceptance (self-efficiency), and the practice of repeated attention refocus. Clinically meaningful improvements were found in measures of emotion regulation, moment-to-moment awareness, and measures of central executive aspects of working memory and attentional regulation. As in our previous study, improvements in quality of life and perceived self-efficacy were also observed. The result shows that emotion regulation can be effectively addressed by influencing attention, self-efficacy, and self-awareness in a mixed population with more severe brain injury.

Study Authors (y)	Country	Study Design and Analysis	Sample Size	Mean Age (y)	Type of Severity (%)	Mechanism of TBI (Up to 3 Most Frequent) (%)	Measure	Key Result
Cantor et al. (2013) [61]	United States	Quantitative	98 Immediately start (IS): 49 Waitlist (WL): 49	45.3 Immediately start (IS): 46.7 Waitlist (WL): 43.9	All	NR	- Problem solving inventory (PSI) - Behavioral assessment of the dysexecutive syndrome (BADS) - Self-awareness of deficits interview - Difficulties in emotion regulation (DERS) - Intervention: STEP program: 12 weeks (9h/wk) of group training in problem-solving and emotional regulation and individual sessions of attention and compensatory strategies training	We found no group differences in neuropsychological or attentional measures, emotional regulation, self-awareness, affective distress, self-efficacy, participation, or quality of life. The attention and emotional regulation of participants did not improve significantly. The main effect of the program may have been problem-solving rather than emotional regulation.

Abbreviations: SCL: Symptom checklist; HRQOL: Health-related quality of life; TBI: Traumatic brain injury; GPS: Global positioning system; BDI: Beck's depression inventory; MRI: Magnetic resonance imaging; CBT: Cognitive behavioral therapy; CFT: Compassion-focused therapy; ABI: Ankle brachial index; DTT: Dithiothreitol; BRIEF: Behavioural regulation index of the behaviour rating inventory of executive function; NR: Not reported.

A total of 17 studies included TBI survivors and their caregivers, families, or the control healthy group (50%). Two studies included a mixed sample of brain injuries (e.g. TBI, stroke, autoimmune, and others) (5%). Furthermore, Table 3 presents the prevalence of emotional problems and their consequences in people with TBI.

4. Discussion

This study was conducted to systematically review the existing studies on emotion regulation in people with TBI. The results indicated that patients with TBI report persistent problems associated with mood disorders and ED following their injury [43, 50]. The evidence indicated that people with TBI dedicate more mental and physiological resources to preserve stable cognitive functioning over time due to their cognitive, social, and behavioral problems in daily life [44, 47, 57]. This can lead to mood disorders [43] because patients may experience difficulties in controlling their emotions despite normal CT scan results, even until 6 months after the injuries [49]. Thus, increased psychological disorders can reduce social activities, and ultimately further pressure on the health care system, society, and the patient's family [62].

Neuroimaging studies have also shown that different cortical and subcortical regions are involved in emotion regulation processes [63]. Numerous TBI-caused molecular and cellular alterations in subcortical structures, including the amygdala and hippocampus [64] and consequently, disruption in regulating the hypothalamic-pituitary-adrenal (HPA) axis can lead to problems in the adaptive response to stress [65]. Over time, this unnatural response to stress can be correlated with post-TBI neuroinflammation and acute psychological and neurological outcomes [65]. In this regard, disrupted neural circuits, including the insular cortex and amygdala prompt compensatory and unusual functional relations of the remaining neural structures and arousal [34]. As a result,

Table 3. The prevalence of emotional problems in TBI

Study Authors (y)	Sample Size	Study Design and Analysis	Emotional Problems Prevalence
Shields et al. (2016) [37]	50 patients with traumatic brain injury in all severity	Quantitative-correlation	38% of the sample have shown a level of depressive symptoms from mild to very severe. 10% of the sample were in the clinical range for anxiety and global distress diagnosis. 62% of the sample reported threat appraisal. 18% of the sample reported avoidance behavior.
Novakovic-Agopian and et al. (2017) [40]	24 veterans with chronic traumatic brain injury	Quantitative-intervention	52% of the sample: involvement in social activities before executive function training. 78% of the sample: involvement in social activities after executive function training.
Grimm and et al. (2017) [42]	3 patients with traumatic brain injury	Quantitative–intervention-mixed method design	16% of the sample improvement in DERS after an eight-week yoga intervention. 6% of the sample improvement in QOLIBRI after eight-week yoga intervention. 5% to 8% of the sample increased in HRQOL after an eight-week yoga intervention.
Finnanger and et al. (2015) [45]	67 patients with moderate to severe traumatic brain injury and 72 controls	Quantitative-prospective cohort study	20% of the TBI sample reported externalizing problems. 36% of the TBI sample have shown working memory problems.
Marsh and Kersel (2006) [47]	62 patients with traumatic brain injury in all severity and 62 caregivers	Quantitative-correlation	52% of the TBI sample have depression. 90% of the TBI sample have emotional dysregulation. 71% of the TBI sample reported behavioral dysregulation.
Sun et al. (2020) [51]	93 veterans with traumatic brain injury	Quantitative-correlation	7.53% of the sample have shown PTSD.
Elbogen et al. (2019) [57]	112 veterans with moderate to severe traumatic brain injury and their family	Quantitative-intervention	25% of the sample reported decreasing in anger over 6 months after cognitive applications for life management (CALM) and brain health training. 8% of the sample reported reducing in control after cognitive applications for life management (CALM) and brain health training.
Beresford and et al. (2005) [59]	18 patients with traumatic brain injury	Quantitative-intervention	78% of the sample improved affective symptoms after treatment with mood-stabilizing medications. 67% of the sample reduced anxiety after treatment with mood-stabilizing medications. 67% of the sample reported either reducing anxiety or improving affective symptoms after treatment with mood-stabilizing medications.

Abbreviations: DERS: Difficulties in emotion regulation scale; QOLIBRI: Quality of life after brain injury; HRQOL: Health-related quality of life; TBI: Traumatic brain injury; PTSD: Post-traumatic stress disorder; CALM: Cognitive applications for life management.

amygdala activity escalates in these patients due to emotional reactions, such as stress and anxiety [35, 51].

Previous studies have reported higher physiological arousal during anger expression in people with TBI compared to normal people [30, 37, 41]. According to Scherer's emotion appraisal theory, emotional responses to internal and external events are manifested through physiological and cognitive appraisal processes [67]. Since the activation of the sympathetic system can substantially affect the cognitive and behavioral manifestations of anger [30], this pattern of response can be a sign of disruptions in the activity of the autonomic nervous system following TBI and may result from injury to the prefrontal cortex and limbic system structures [39, 52, 57]. In this regard, studies have reported that frontal lobe vulnerability [18-20, 52] and prefrontal cortex and posterior cingulate cortex (as well as precuneus) dysfunction cause psychological and mood disorders [46]. So that people with TBI show symptoms of ED in the form of depression and anxiety [36, 45, 46, 48, 56], which can affect their recovery from trauma [49].

Furthermore, interpersonal differences in coping styles can influence the continuation of post-injury mood complaints [68]. People with TBI experience more problems in processing emotional reactions to negative facial emotional signs compared to others' positive facial emotional signs [32, 49]. This reduces their ability to imitate negative faces andautonomous reactions to negative faces, recognize negative faces [69], and control negative emotions [49].

Moreover, disruptions in higher-level cognitive functions (e.g. response inhibition and cognitive flexibility), following TBI, possibly imperil impulse control and re-evaluation of emotional events [37]. When patients experience more negative effects, they face amplified problems, such as loss of concentration in purposeful activities [70] and problem-solving with diminished flexibility to manage these emotions. The intensity of these changes depends on a patient's ability to organize affects and show flexibility in utilizing their potential [49]. Since emotional knowledge has a crucial role in emotion regulation [71] and people with TBI experience problems in recognizing and processing unconscious emotions (physiological or bodily affects) and conscious affects, they encounter difficulties in regulating their emotions [32].

5. Conclusion

Although the recovery in clinical and medical care has significantly reduced TBI-related fatality [72], long-term outcomes associated with post-injury emotional and mental distress and dysregulation have rarely been analyzed in terms of TBI treatment. The nature of brain injury is very complicated, and effective factors, such as demographic, biological, medical, and psychological aspects should not be neglected [49]. ED notably contributes to TBI-caused outcomes, and research is yet to determine whether physical injuries continue mental symptoms or vice versa. Therefore, medical and clinical psychology care should be equally considered for people with TBI, and a more comprehensive approach can be adapted to treat people with TBI and improve their quality of life.

Limitation

The first limitation of this study was the absence of divided groups in terms of TBI severity (mild/moderate/severe). Moreover, because mild traumatic injuries (mTBIs) are more prevalent than other TBIs worldwide, it is essential to analyze the effects of mTBI on emotional dysregulation. Accordingly, future studies are recommended to use standardized TBI intensity measures and report the correlation between intensity and performance at individual levels. Such an approach can be more helpful in determining the existence of a correlation between TBI intensity and emotion recognition disorder. Furthermore, it is recommended to design and test intervention protocols in the form of randomized clinical trials to resolve post-TBI emotional dysregulation. A main limitation of this study is that no gold standard for diagnosing emotional dysregulation existed, in other words, it included a spectrum of emotional problems in this study. Although the findings showed the existence of post-TBI emotional dysregulation, this study cannot accurately confirm whether TBI exclusively leads to ED or whether other problems following TBI may cause dysregulation. Hence, future studies can help develop certain interventions and rehabilitation methods by utilizing general diagnostic criteria while assessing ED. Moreover, since pre-morbidity disorders were not considered in this study, it is recommended to emphasize pre-morbidities in future studies.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Biomedical Research Ethics Committee of University of Guilan (Code: IR.GUILAN.REC.1400.038). All patients participating in this study filled out the written informed consent form.

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Authors' contributions

Conception and design: Sajjad Rezaei; Data collection: Maryam Jafroudi; Data analysis, data interpretation and critically revising the article: Maryam Jafroudi and Sajjad Rezaei; Drafting the article: Maryam Jafroudi; Review and final approval: Sajjad Rezaei.

Conflict of interest

The authors declared no conflict of interest.

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