

Post-traumatic stress disorder in major accidents: systematic review and meta-analysis

Transtorno de estresse pós-traumático em acidentes ampliados:
revisão sistemática e metanálise

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ABSTRACT | Major accidents are defined as accidents whose consequences spread spatially and temporally from acute events related to production activities. Exposure to these accidents has psychological impacts on individuals, including the development of mental disorders such as posttraumatic stress disorder. Thus, the aim of this study was to identify and analyze the evidence available in the literature on the relationship between exposure to major accidents and the development of posttraumatic stress disorder. To that end, a systematic literature review was conducted using the Web of Science and Google Scholar databases, followed by a meta-analysis based on the results of the selected studies. Twenty-six articles were selected, related to 14 major accidents, including 11 longitudinal and 15 cross-sectional studies. The studies were conducted from 2 months to 36 years after the major accident, comprising 24,276 participants. The methods, techniques and instruments used varied between studies. The meta-analysis indicated a prevalence of posttraumatic stress disorder of 18.57% (confidence interval 13.80-23.87; $I^2 = 96.22\%$). Posttraumatic stress disorder symptoms persisted over the years after the accident. The prevalence of posttraumatic stress disorder after exposure to major accidents was found to be higher compared to that of the general population. Risk factors for posttraumatic stress disorder included intensity of exposure, occurrence of physical damage, lack of social support, and economic losses. The results indicate the need for planned, rapid start and long-term interventions.

Keywords | posttraumatic stress disorder; disaster; major accidents.

RESUMO | Acidentes ampliados são definidos como acidentes cujas consequências se propagam espacial e temporalmente a partir de eventos agudos relacionados a atividades de produção. A exposição a esses acidentes apresenta impactos psicológicos nos indivíduos, incluindo o desenvolvimento de transtornos mentais, como o transtorno de estresse pós-traumático. Dessa forma, o objetivo deste estudo foi identificar e analisar as evidências disponíveis na literatura sobre a relação entre exposição a acidentes ampliados e desenvolvimento de transtorno de estresse pós-traumático. Para isso, foi realizada uma revisão sistemática da literatura utilizando as bases de dados *Web of Science* e *Google Acadêmico*, seguida de metanálise a partir dos resultados dos estudos selecionados. Foram selecionados 26 artigos relacionados a 14 acidentes ampliados, incluindo 11 pesquisas longitudinais e 15 transversais. Os estudos foram realizados entre 2 meses e 36 anos após o acidente ampliado, compreendendo 24.276 participantes. Os métodos, as técnicas e os instrumentos empregados apresentaram variação entre os estudos. A metanálise indicou uma prevalência de transtorno de estresse pós-traumático de 18,57% (intervalo de confiança 13,80-23,87; $I^2 = 96,22\%$). Os sintomas de transtorno de estresse pós-traumático se mantiveram ao longo dos anos após o acidente. Observou-se que a prevalência de transtorno de estresse pós-traumático após a exposição a acidentes ampliados é maior quando comparada com a população em geral. Os fatores de risco para transtorno de estresse pós-traumático incluem a intensidade da exposição, a ocorrência de danos físicos, a falta de suporte social e prejuízos econômicos. Os resultados indicam a necessidade de intervenções planejadas, de início rápido e de longo prazo.

Palavras-chave | transtornos de estresse pós-traumático; desastres; acidentes ampliados.

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INTRODUCTION

If, on the one hand, the growth of industrial activities is associated with economical development, on the other hand, it is related to the increase of risks associated with these activities. These risks become more visible, and even shocking, when major disasters occur, such as the one in Chernobyl, in Bhopal, and, more recently and closer to our context, Mariana's and Brumadinho's dam collapses.

Accidents such as these share characteristics that place them under a different category of major accidents. The definition of a major accident is associated with the fact that these accidents spread spatially and temporally from an acute event (explosions, fires, leaks, etc.) related to industrial activities, reaching different environments, properties, and people. This type of accident usually involves the release of a significant amount of energy from one or more hazardous materials in industrial plants or during the processes of storage and transportation.¹

Besides the immediate consequences of this type of accident, the psychosocial consequences that impact the affected population are multiple and tend to spread over time,¹ being associated with social and individual variables.² Especially when it comes to the development of mental disorders, exposure to major accidents may be a traumatic event. Thus, it is a potentially triggering or aggravating factor for changes in stress reactions in these individuals, and in its chronic form it is related to the development of posttraumatic stress disorder (PTSD).²

With a prevalence of 2.1% to 2.3% in the overall population,³ PTSD is considered to be a common mental disorder, although it may be misdiagnosed because its symptoms are similar to those of anxiety and depression or other reactions to stress.³ The current diagnostic criteria adopted by the Diagnostic and Statistical Manual of Mental Disorders-5 (DSM-5) generally comprehend the presence of a) exposure to a traumatic event, including experiencing it directly, witnessing the event, or being intensely exposed to aversive details of the event; b) intrusive symptoms, such as memories, dreams, dissociative reactions, intense psychological suffering, and intense physiological reactions; c) avoidance behavior; d) negative cognitive

and mood effects, including distorted thoughts and emotional blunting; and e) changes in reactions and excitement, such as hypervigilance, irritability, angry outbursts, and sleep disturbances. These criteria must last for more than a month, cause clinically significant suffering and social damage, and not be derived from substance use.³

The current 11th revision of the World Health Association's International Classification of Diseases (ICD-11) presents a simplified approach for diagnosing PTSD that includes the classification of the basic and complex forms of the disorder. To be diagnosed with PTSD, the patient must have been exposed to a traumatic event and must show at least one symptom of re-experiencing, avoidance, and sense of threat that lasts several weeks and causes significant functional impairment.⁴

In situations of exposure to large-scale traumatic events, being exposed to disasters caused by human actions, such as major accidents, tends to be associated with higher PTSD rates than being exposed to natural disasters.² The socioeconomic conditions of the affected population also influence the prevalence of PTSD after large-scale accidents, with a higher probability of developing PTSD in poorer regions, especially when the population's productive and income conditions are impacted.^{2,3}

When considering the impact of major accidents and the personal and social impairments related to PTSD, it is necessary to understand how these specific events relate to the development of PTSD from a scientific point of view, given the unique characteristics of these accidents, and from a practical point of view, as such understanding would allow the planning of interventions that include the potential risks. Therefore, this study aimed to identify and analyze the evidence on the association between exposure to major events and the development of PTSD through a systematic review of the literature and meta-analysis.

METHODS

Based on the PICO (population, interest, context) for non-clinical research, the present review sought to

answer the following guiding questions: what are the contributing factors and what is the incidence of PTSD in people exposed to major accidents?

The initial search was conducted using the Publish or Perish software, version 6.49, on Web of Science and Google Scholar databases. The inclusion of Google Scholar is justified by the intent of accessing locally relevant production, since regional studies are not so easily found on large databases. In this stage, the following descriptors were used: “*estresse pós-traumático*” AND “*acidentes ampliados*” OR “*acidentes em larga escala*” OR “*acidente industrial*” OR “*acidente tecnológico*” OR “*desastre*”, and their English equivalents (“post-traumatic stress” AND “major accidents” OR “great scale accidents” OR “industrial accident” OR “technological accident” OR “human-made disaster”).

The alternative terms to “major accidents” were used to broaden the scope of the search and to retrieve articles that did not use the strict term but that addressed accidents that could be classified accordingly.

The inclusion criteria were as follows: a) articles published in pair-review journals, b) with an empirical design, c) focusing on major accidents, and d) that had PTSD as a study variable. Theses, dissertations, theoretical studies, reviews, editorials, and studies focusing on natural disasters or on other type of disaster (air, rail, road, or maritime disasters, and terrorist attacks) were excluded. The initial sample consisted of 1,075 publications. After exclusion of duplicate publications, application of inclusion and exclusion criteria, and initial reading, the final sample resulted in 26 articles (Figure 1).

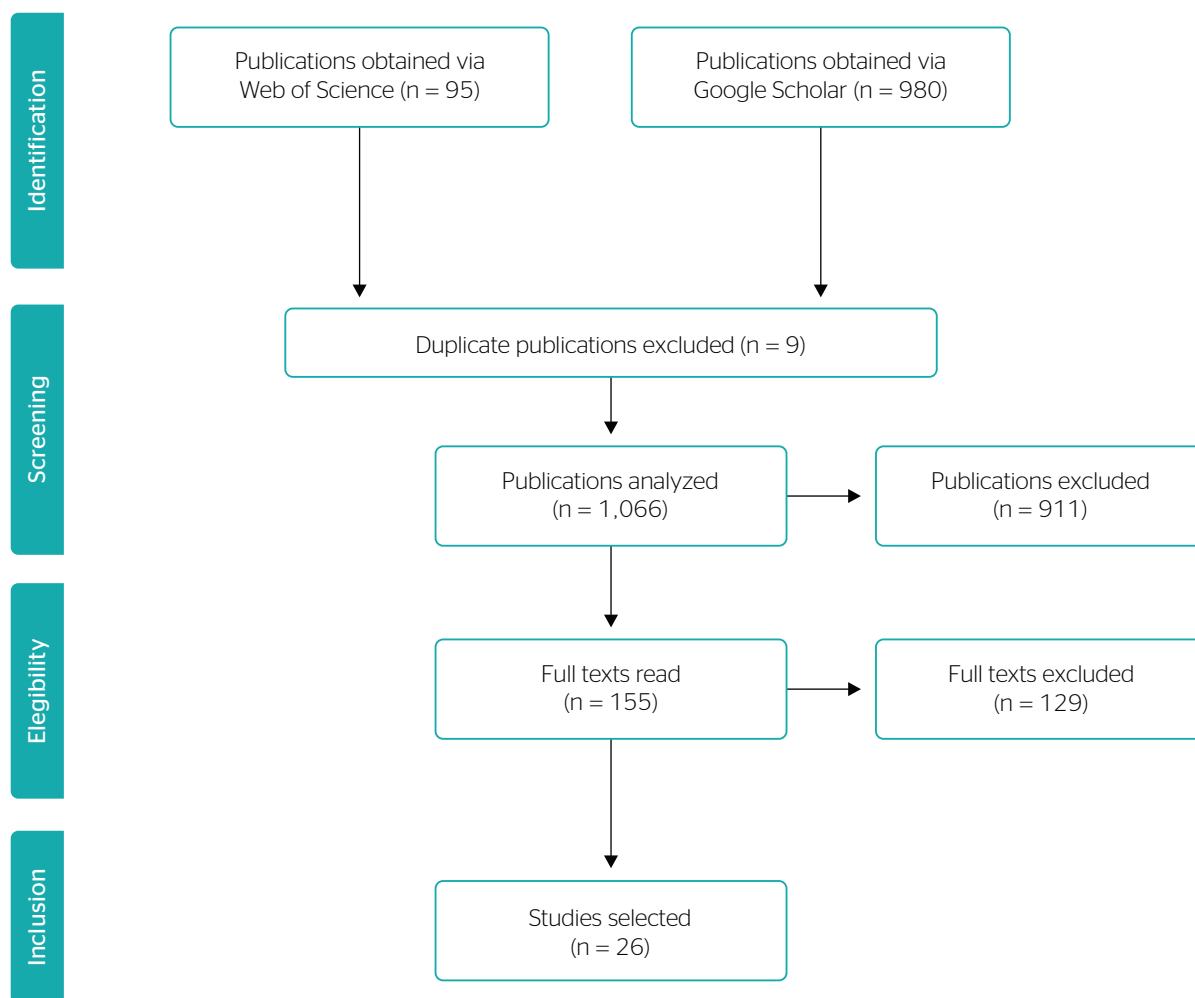


Figure 1. Article selection flowchart for systematic review.

For the meta-analysis study, the random effect model and heterogeneity as assessed by calculating the I-square (I^2) statistic were used. The occurrence of small study effect was verified by visual inspection of the funnel graph. The analyses were performed using the MedCalc statistical software, version 19.0.6.

RESULTS

Based on the final selection of articles, studies investigated a total of 14 major accidents (Table 1). It was found that 50% of the sample addressed the accident in Enschede, the accidents in Piper Alpha and Deepwater oil platforms, or the Buffalo Creek disaster.

Overall, the 26 studies had 24,276 participants, including survivors, residents in the affected areas, health care professionals, firefighters, rescue teams, and individuals who composed the control groups. The composition of samples and the main results are shown in Table 2.

Only six studies made use of control groups: Breton et al.,⁷ Morgan et al.,¹¹ Morren et al.,¹⁴ Adams

et al.,¹⁹ Boe et al.,²⁰ and Holgersen et al.²¹ The control groups used were composed in order to maintain the sociodemographic characteristics of participants exposed to the major accidents. For example, the study by Breton et al.⁷ used a control group of children paired by age, sex, and family socioeconomic status and randomly selected from records in the province of Quebec.

Of the articles analyzed, 11 (42.31%) had a longitudinal design, and 15 (57.69%), a cross-sectional one. Cross-sectional studies were conducted from 2 months²⁶ to 20 years after exposure to the accident.¹⁹ Adams et al.¹⁹ took advantage of the participation of women in a longitudinal study on the consequences of the Chornobyl disaster to conduct a cross-sectional study on the mental health of the children of these women.

Longitudinal studies covered periods ranging from 2²⁷ to 36 years¹² after the accidents. The study by Bramsen et al.¹⁵ was based on a sample of World War II veterans who had already been followed in another study on mental health. However, since they lived in Enschede at the time of the firework factory explosion,

Table 1. Distribution of studies by major accident

Major accident	Year	Studies	
		n	%
Explosion in a fireworks deposit of SE Fireworks, Enschede, the Netherlands	2000	5	19.23
Disaster in the Piper Alpha oil platform, North Sea, Scotland	1988	3	11.54
Disaster in the Deepwater oil platform, Gulf of Mexico, United States	2010	3	11.54
Disaster in Buffalo Creek due to the burst of a coal slurry impoundment dam managed by Pittston Coal Company, County of Logan, West Virginia, United States	1972	2	7.69
Disaster in the Alexander L. Kielland oil platform, North Sea, Norway	1980	2	7.69
Exxon Valdez oil spill, Prince William Sound, Alaska, United States	1989	2	7.69
Explosion in the AZF fertilizing factory, Toulouse, France	2001	2	7.69
Transposition of the Vajont Dam, Longarone, Italy	1963	1	3.85
Coal mine disaster in Aberfan, Wales	1966	1	3.85
Nuclear Chornobyl disaster, Pripjat, Ukraine	1986	1	3.85
Fire in a polychlorinated biphenyl warehouse, St-Basile-le-Grand, Montreal, Canada	1988	1	3.85
Train disaster with chlorine gas spill, Graniteville, South Carolina, United States	2005	1	3.85
Fukushima Daiichi nuclear disaster, Ōkuma, Fukushima, Japan	2011	1	3.85
Gas leakage in Kaohsiung, Taiwan	2014	1	3.85

Table 2. Synthesis of the analyzed studies by authors, sample, research design, and main results

Authors	Sample	Study design	Main results
Ersland et al. ⁵	134 rescuers	Cross-sectional	Symptoms compatible with PTSD in 24% of participants, with less severe effects in most experienced workers.
Green et al. ⁶	120 adult survivors	Longitudinal	Decrease in the rate of PTSD of 2.1 to 1.3%; however, 25% of participants remained with significant psychiatric changes.
Breton et al. ⁷	87 children exposed to poisonous cloud and 87 children in the control group	Cross-sectional	Scores of PTSD symptoms were significantly higher in children exposed to the accident. Internalized symptoms are more common than observable behavioral symptoms.
Green et al. ⁸	99 adults who, in 1974, composed a sample of 207 evacuated children	Longitudinal	Decrease in the baseline incidence of PTSD from 32% to 7%. All current PTSD cases in the sample were women.
Arata et al. ⁹	126 fishers in the area affected by the disaster	Cross-sectional	In the sample, 34% of men and 40% of women presented symptoms compatible with PTSD associated with deteriorated social relationships and reduced physical health.
Hull et al. ¹⁰	33 survivors	Cross-sectional	Ten years after the disaster, 21% of survivors presented symptoms compatible with PTSD. The occurrence of physical injury, personal experience, and survival guilt were associated with higher levels of posttraumatic symptoms.
Morgan et al. ¹¹	41 survivors and 72 participants in the control group	Cross-sectional	Of the survivors, 46% had been diagnosed with PTSD at some point since the accident, and 29% met diagnostic criteria for PTSD.
Favaro et al. ¹²	39 survivors	Cross-sectional	Diagnosis compatible with PTSD in 26% of participants; 33% had partial PTSD symptoms. Risk factors were identified as female gender and number of losses of first-degree relatives in the disaster.
Palinkas et al. ¹³	188 Alaskan natives and 371 Euro-American exposed to disaster in 1989	Cross-sectional	High level of impairment in social relationships was associated with PTSD 1 year after the disaster in both groups. However, low family support, participation in spill clean-up activities, and decline in work activities were significantly associated with PTSD in Alaskan natives.
Morren et al. ¹⁴	246 volunteer firefighters who worked in the disaster and 71 participants in the control group	Cross-sectional	Only 0.9% of participants had symptoms compatible with PTSD, a percentage below the estimated prevalence for the Dutch population at the time of the study.
Bramsen et al. ¹⁵	257 World War II survivors who were exposed to the disaster	Longitudinal	Exposure to the disaster had a significant effect on the reactivation of PTSD.
Dirkzwager et al. ¹⁶	896 survivors	Longitudinal	A total of 18% of survivors presented PTSD symptoms. A significant association was found between PTSD and vascular, musculoskeletal, and dermatologic changes.
Boe et al. ¹⁷	48 survivors	Longitudinal	In the sample, 18.8% of survivors experienced reactivation of PTSD, of which 4.2% were cases of late-onset PTSD. Participants with reports of intrusive from the accident during sleep had a greater likelihood of reactivation of PTSD.
Bui et al. ¹⁸	388 participants in collection 1; 200 in collection 2; 129 in collection 3; and 179 in collection 4	Longitudinal	PTSD symptoms developed up to 15 months after the disaster and, once developed, they tend to remain stable. The likelihood of developing PTSD symptoms increases according to the increase in the intensity of the acute stress episode and peritraumatic dissociation.
Adams et al. ¹⁹	254 mothers of children evacuated during the accident; 295 mothers of children who were classmates of evacuated children; and 304 mothers in the control group	Cross-sectional	The occurrence of PTSD twice to three times greater among mothers of evacuated children. Data indicate the chronicity of the disorder.
Boe et al. ²⁰	48 survivors and 62 participants in the control group	Longitudinal	Full diagnosis of PTSD in 6.1% of survivors; diagnosis of subsyndromal PTSD with depression in 14.6% of the sample.

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Table 2. Continued

Authors	Sample	Study design	Main results
Holgersen et al. ²¹	75 survivors and 92 participants in the control group	Longitudinal	Twenty-seven years after the disaster, 8.12% of survivors remained with PTSD symptoms. Decline in stress levels up to the 8 th week after exposure predicts the non-establishment of PTSD.
Diene et al. ²²	13,129 workers in the city of Toulouse	Cross-sectional	Higher prevalence of PTSD symptoms in workers in the area closer to the epicenter (12% for men and 18% for women). Significant association between professional category and symptoms.
Ginsberg et al. ²³	225 victims	Cross-sectional	A total of 37% of participants exhibited symptoms compatible with PTSD, and 27% presented panic symptoms.
Smid et al. ²⁴	1,083 residents in the affected area	Longitudinal	Late-onset PTSD was associated with high education level, severe disaster exposure, and perceived lack of social support.
van der Velden et al. ²⁵	1,083 residents in the affected area	Longitudinal	During the 10 years after the disaster, 6.7% of participants developed symptoms compatible with PTSD.
Shigemura et al. ²⁶	1,411 employees at Daiichi and Daini plants	Cross-sectional	Peritraumatic distress was a predictor of posttraumatic stress responses.
Hansel et al. ²⁷	314 participants in the affected areas	Longitudinal	There was no decrease in the rate of PTSD over the study period.
Bell et al. ²⁸	213 participants living in the areas affected by the disasters	Cross-sectional	People exposed to oil had a 2.81-fold higher likelihood of being diagnosed with PTSD, with a predominance of avoidance-oriented coping strategies.
Nugent et al. ²⁹	1,997 women who resided in coastal areas affected by the disaster	Cross-sectional	Significant effects of income and ethnicity on the prevalence of PTSD symptoms, with black women having a greater likelihood of developing PTSD.
Shieh et al. ³⁰	388 residents in the affected region	Cross-sectional	Symptoms compatible with PTSD in 8.8% of participants and with PTSD associated with depressive disorder in 2.3%, being both significantly associated with physical injuries and financial problems resulting from the disaster.

PTSD = posttraumatic stress disorder.

were exposed to a second traumatic event, allowing for the assessment of the cumulative effects of exposure to multiple traumatic events.

Among the instruments employed, the Impact of Event Scale (IES), and his versions, was the most used (nine studies, 34.6%),^{5,8,10,11,15,19,22,24,26} followed by Symptom Check List-90R (five studies, 19.2%),^{6,9,14,16,19} versions of the General Health Questionnaire (four studies, 15.4%),^{10,11,15,21} versions of the Structured Clinical Interview for the DMS used at the time of the study (four studies, 15.4%),^{8,12,17,20} and Post-Traumatic Stress Disorder Self-Rating Scale (PTSD-SRS) (three studies, 11.5%).^{14,16,24} The IES is an instrument to assess stress with regard to everyday events, whereas the other instruments are designed to identify or to track mental disorder symptoms in general, except for the PTSD-SRS, which is specific for PTSD. The study by Ginsberg

et al.²³ used Gaussian dispersion models to estimate the degree of exposure to chlorine gas in the Graniteville accident. The study by Diene et al.,²² instead, made use of a geospatial analysis program to assess the closeness of sample participants with regard to exposure to the explosion in the AZF fertilizer factory, in Toulouse.

Of the articles selected, 15 presented data on the prevalence of PTSD for the study sample. Therefore, only these studies were included in the meta-analysis. Figure 2 shows the results of the calculated prevalence of studies with its 95% confidence interval (95%CI).

High heterogeneity was observed ($\chi^2 (14) = 369.93$; $p < 0.0001$; $I^2 = 96.22\%$; 95%CI 94.93-97.17). In view of this heterogeneity, the estimation of total effects for prevalence by the random effects model, the most indicated one, yielded a prevalence of 18.57% (95%CI 13.80-23.87).

Meanwhile, visual inspection of funnel graph did not identify any small studies effect (Figure 3), which may indicate that the observed heterogeneity is related to the methodological aspects of the studies. Although Figure 3 reveals that study were slightly more concentrate on the right side of the graph, the result shows a symmetric distribution, which suggests that there is no publications bias.

Risk factors for the development of PTSD in cases of major accidents found in the studies were the following: intensity of exposure to the accident, sex, occurrence of physical damages, lack of social support, and economic losses or subsistence difficulties. The same risk factors are involved in PTSD reactivation¹⁴ and in the presence of intrusive symptoms, especially during sleep.^{16,19,20} Conversely, protective factors to PTSD are related to level of professional experience and to the ability of coping with peritraumatic events.^{5,26}

DISCUSSION

Considering that PTSD was characterized as an independent disorder with particular pathognomonic characteristics only in 1980, the lack of previous

studies on the theme is understandable. However, the introduction of PTSD allowed for its use in retrospective studies of accidents that occurred before the characterization of PTSD, such as the accidents of Vanjot,¹² Aberfan,¹⁴ and Buffalo Creek.^{6,8} Furthermore, the conduction of studies on major accidents presents

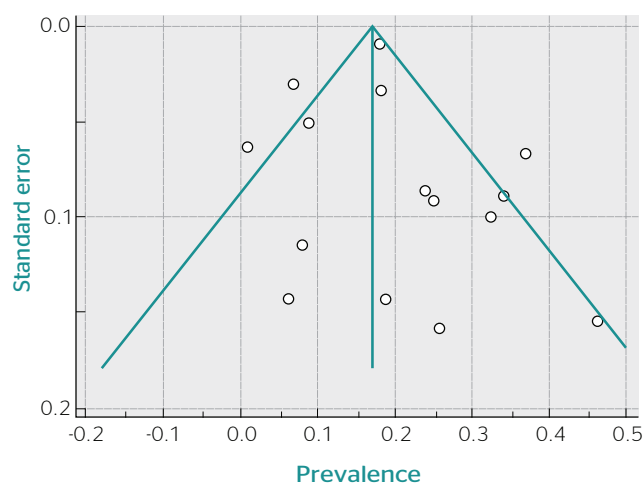


Figure 3. Funnel graph of the prevalence of posttraumatic stress disorder in each study by the standard error of the studies.

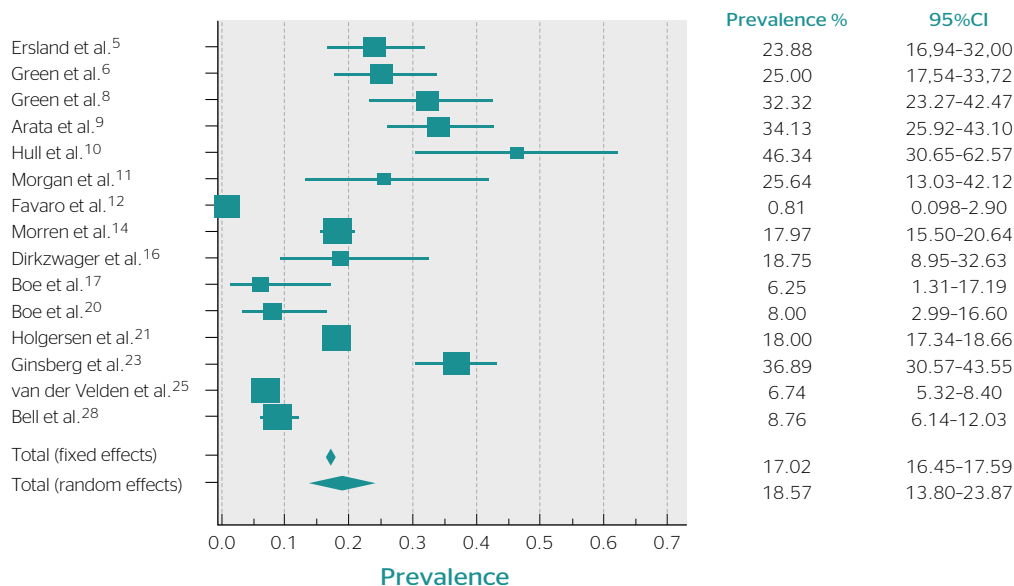


Figure 2. Prevalence of posttraumatic stress disorder in people exposed to major accidents. 95%CI = 95% confidence interval.

practical barriers involving access to the population, research design, and control of variables prior to the major accident. This is one of the factors that hamper the use of a study method with greater control over research on major accidents. Conversely, cross-sectional and longitudinal investigations are essential in this context, since they enable both to ascertain the prevalence of PTSD in the affected population and to monitor and promote mental health interventions.

The variety of participants in the studies (survivors, rescuers, residents in the affected areas, among others) and the diversity of age groups are in line with the very concept of major accidents. This variation is necessary due to type of accident; meanwhile, the high heterogeneity observed may be related to variability of study samples, since they are very different in terms of size, composition, and socioeconomic context.^{6,12,30} Thus, caution is warranted with regard to inferences based on results of meta-analyses.

The results showed that the prevalence indicated in the studies that composed the sample of the present research is higher than the prevalence of PTSD estimated for the general population, i.e., from 2.1 to 2.3%.¹³ This finding reinforces the understanding that major accidents and their impact are potential triggers of the disorder. Pointing in the same direction, longitudinal studies identified the persistence of PTSD symptoms even three decades after the exposure to the accident,¹⁰ including when related to the loss of family members.²⁷ This information deserves attention and may support the development of health promotion programs for this population, especially with regard to the duration of these interventions.

The results indicating association between intensity of exposure to the accident, occurrence of physical damage, lack of social support, and economic losses are consistent with risk factors for PTSD indicated in the literature.¹² Consistent with current findings describing the development of PTSD by people who were not directly exposed to the accident but had contact with victims or with new about the fact, evidence of PTSD was found in people in these conditions.¹⁹ This information raises a debate with regard to the coverage of interventions implemented as a result of major accidents. Effective interventions should not be

restricted to the directly exposed population and thus are required to cover the whole community.⁶

Evidence on longitudinal studies, more specifically those focused on the reactivation of PTSD, is consistent with the proposal of CID-11 that PTSD is a complex phenomenon.¹⁶ This condition goes beyond diagnostic criteria already established for the disorder, since it includes severity and persistence of 1) affective regulation problems; 2) prominently negative self-referential beliefs; and 3) difficulties in maintaining a relationship.

Altogether the results point to the need of rapid start and long-term interventions with direct and indirect victims of major accidents, especially with socially vulnerable populations or who experienced losses in their subsistence activities.^{8,28} This corroborates what has already been indicated in the literature with regard to the need of planning and implementing early interventions adapted to the characteristics of the accident and focusing on high-risk groups,² especially in contexts in which socioeconomic conditions are worsened by the accidents.^{2,3}

FINAL CONSIDERATIONS

Major accidents have a significant relationship with the development of PTSD, a relevant factor within a society that is increasingly more industrialized, complex, and with increasingly more severe technological risks.¹ This relationship should be considered when planning and implementing interventions with populations exposed to this type of accident.

Despite the significant occurrence of major accidents in the Latin-American context, the lack of studies with populations affected in this region indicates an important gap. The development of investigations in this region becomes necessary, especially when considering the influence of sociodemographic and cultural variables on the development of PTSD.

On one hand, the great methodological variation of the assessed studies increases the amount of generated information; on the other hand, it eventually limits generalizations in this research. Methodological development is thus essential for achieving advances

in the field, including the development of instruments containing the most recent diagnostic criteria for PTSD.^{13,14,18}

AUTHOR CONTRIBUTIONS

CMLR was responsible for study conceptualization, project administration, methodology, investigation,

formal analysis, software, and writing – original draft and review & editing. JBB was responsible for methodology, investigation, formal analysis, writing – original draft and review & editing. HMN was responsible for investigation, formal analysis, resources, visualization, and writing – original draft and review & editing. All authors approved the final version submitted and assume public responsibility for all aspects of the work.

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