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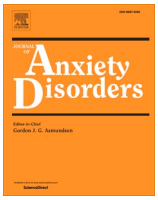

The relationship between tonic immobility and the development, severity, and course of posttraumatic stress disorder: Systematic and meta-analytic literature review

Bruno Messina Coimbra [a,b,1,*], Chris Maria Hoeboer [a], Mirjam van Zuiden [c], Rachel E. Williamson [d], Ana Teresa D'Elia [b], Andrea Feijo Mello [b], Marcelo Feijo Mello [b], Miranda Olff [a,e]

[a] Amsterdam UMC, University of Amsterdam, Department of Psychiatry, Amsterdam Public Health Research Institute and Amsterdam Neuroscience Research Institute, Amsterdam, the Netherlands
[b] Program for Research and Care on Violence and PTSD (PROVE), Department of Psychiatry, Universidade Federal de São Paulo (UNIFESP), São Paulo, Brazil
[c] Department of Clinical Psychology, Utrecht University, Utrecht, the Netherlands
[d] Department of Psychology, University of Montana, Missoula, MT, United States
[e] ARQ National Psychotrauma Centre, Diemen, the Netherlands

A B S T R A C T

Background: Tonic immobility (TI) is a reflexive, involuntary response that causes motor inhibition, vocal suppression, and analgesia. TI is elicited by extreme fear and perception of entrapment in a life-threatening situation. Research suggests that TI is a frequent peritraumatic response and may be related to subsequent posttraumatic stress disorder (PTSD). However, findings are mixed and, as of yet, no systematic or meta-analytic review examining associations between TI and PTSD has been published.

Objective: We systematically and meta-analytically reviewed the literature and investigated whether TI is associated with the development, severity, and course of PTSD. Additionally, we evaluated whether different types of traumatic events are differentially associated with TI, and whether TI severity differs according to sex.

Methods: A systematic literature search was conducted using Embase, PubMed, PsycINFO, and Scopus. Meta-analyses were performed on the included articles.

Results: We identified 27 eligible articles. We found a significant association between TI and PTSD symptom severity ($r = 0.39$, 95% CI: 0.34–0.44; $p < .0001$). TI was more severe among females (Cohen's d=0.37, 95% CI: 0.25–0.48; $p < .0001$) and was more often elicited in situations involving interpersonal violence. We found limited longitudinal data to perform a meta-analysis of the association between TI and the development and/or course of PTSD. However, the literature available seems to support the role of TI in both the development and course of PTSD.

Conclusions: Peritraumatic TI is associated with PTSD symptom severity, occurs more often during interpersonal violence, and is more severe among females. More longitudinal research is needed to investigate the role of TI in psychopathology development and course.

1. Introduction

Tonic immobility (TI) is a state of motor inhibition and muscular rigidity that can occur in response to the perception of imminent life-threat (Volchan et al., 2017). It is a reversible and involuntary, reflexive reaction, often characterized by catatonic-like postures, parkinsonian-like tremors, and intermittent periods of eye closure or fixed gaze (de Kleine et al., 2018; Marx et al., 2008; Schauer & Elbert, 2010). Unlike freezing, when individuals detect a threat and prepare for action by becoming highly vigilant and responsive, TI manifests in relative unresponsiveness to stimuli, waxy flexibility, and analgesia (Bovin et al., 2014; Gallup & Rager, 1996) and is elicited by extreme fear and by the perception of inevitable entrapment (Bovin et al., 2008). TI is considered the last stage of the human defense cascade, after all the initial attempts to avoid danger have failed, and escaping is no longer an option (Hagenaars et al., 2014; Kozlowska et al., 2015).

TI has been extensively studied in animals for over three centuries, but only recently has been linked to human reactions during life-threatening situations (Volchan et al., 2011). Experiences of paralysis and vocal suppression reported by survivors during sexual violence was

* Correspondence to: Amsterdam UMC, University of Amsterdam, Department of Psychiatry, Amsterdam Public Health Research Institute and Amsterdam Neuroscience Research Institute, Meibergdreef 9, 1105 AZ Amsterdam, the Netherlands.
E-mail address: b.messinacoimbra@amsterdamumc.nl (B.M. Coimbra).
[1] (ORCID: 0000–0001-5092–9625)

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first suggested in the late 1970s to be a TI manifestation in humans analogous to TI observed in animals (Suarez & Gallup, 1979). TI is thought to occur in trapped animals as an attempt to reduce continued violence, thus providing a chance to survive, as the predator may lose interest in the prey and release it (Bastos et al., 2016; Bracha et al., 2004). As observed in animals, TI during sexual assault may occur due to the intense fear elicited by the inescapability of an extreme life-threatening situation, possibility leading the perpetrator to lose interest and stop the aggression (Bovin et al., 2014).

A growing body of evidence suggests that TI is a frequent reaction during sexual assaults, ranging from 37% to 52% of victims (Fusé et al., 2007; Galliano et al., 1993; Heidt et al., 2005). However, more recent evidence concluded that TI may also occur during other types of traumatic experiences, such as when experiencing other forms of interpersonal violence (Bados et al., 2008; Portugal et al., 2012), and, though less frequently, natural disasters and accidents (Kalaf et al., 2017). Additionally, the occurrence of TI may be associated with a higher risk of developing posttraumatic stress disorder (Cantor, 2009).

Posttraumatic stress disorder (PTSD), a severe and often debilitating psychiatric disorder triggered by exposure to a traumatic event, is characterized by intrusive memories and thoughts about the traumatic event, persistence avoidance of trauma-related reminders, negative alterations in mood and cognitions, and hyperarousal and hyperreactivity (American Psychiatric Association, 2013). PTSD is highly prevalent in society, with a higher incidence for interpersonal violence (including sexual assault) than other types of traumatic events (Kessler et al., 2017; Kilpatrick et al., 2013; Luz et al., 2016; Ribeiro et al., 2013). Females develop PTSD and exhibit persistent PTSD symptoms more often than males, although the reasons for these observed sex/gender differences are not fully elucidated (Olff et al., 2007; Tolin & Foa, 2006). Clinical research estimates that nearly 40% of patients with PTSD develop a chronic course of the disorder (Santiago et al., 2013). Such a chronic course is associated with higher comorbidity with other psychiatric disorders (Swart et al., 2020; Walter et al., 2018), increased risk of health decline (Byers et al., 2014), suicidality (Krysinska & Lester, 2010), and mortality (Boscarino, 2006).

Given the societal burden and public health concern that PTSD represents, researchers have begun to focus on identifying peritraumatic reactions related to posttraumatic adjustment (Rizvi et al., 2008). Efforts to measure reactions during or shortly after trauma exposure aim to elucidate the role of immediate responses to trauma in the development of psychopathology (Brunet et al., 2001). Studies have shown that individuals react to traumatic experiences in a complex and well-coordinated manner, initially by an appraisal of an environmental stressor that exceeds the individual's resources and coping abilities, followed by a variety of emotional (e.g., fear, disgust, helplessness, horror), physiological (e.g., sweating, elevated heart rate, nausea), behavioral (e.g., fighting, fleeing), and cognitive responses (Bovin & Marx, 2011; Danböck et al., 2021; Tran & Beck, 2019). Cognitive responses may include peritraumatic dissociation (PD), a common peritraumatic reaction widely studied in PTSD literature (Marmar et al., 1998; Zylberstajn et al., 2022), and peritraumatic appraisal of threat (McNally, 2003; Olff et al., 2005).

Cumulative evidence supports the value of peritraumatic reactions as risk factors of subsequent PTSD development, course, and symptom severity (Lawyer et al., 2006; Lensvelt-Mulders et al., 2008; van der Hart et al., 2008). However, compared to other peritraumatic reactions, TI remains understudied in PTSD literature (Portugal et al., 2012), despite existing studies showing that it is a common peritraumatic reaction (Kalaf et al., 2015; Rocha-Rego et al., 2009). Moreover, unlike PD, where there is reduced awareness of the situation and fragmented memories of the traumatic event (Schauer & Elbert, 2010), there is no disruption in memory and consciousness among individuals experiencing TI. Although unresponsive to stimuli, the individual remains exceptionally alert and aware (Bovin et al., 2014). Despite the occurrence of TI as a mechanism that gives protection from further violence, the reflexive and involuntary paralysis experienced during TI, while the individual is fully conscious of danger and unable to move, is likely a frightening experience itself, and possibly maladaptive in the face of extreme threat (Marx et al., 2008).

The most often used instrument to measure TI is the 10-item Tonic Immobility Scale (Bovin et al., 2014; Forsyth et al., 2000). The 10-dimensional items of the TIS include components related to the tonic immobility factor (seven items) and the fear factor (three items, Fiszman et al., 2008; Massazza et al., 2021; Möller et al., 2017; Van Buren & Weierich, 2015). Additionally, shortened versions of the TIS have been validated, some of which exclude the fear factor-related items and focus on the motor aspects of TI, as the seven-item TIS (Bovin et al., 2014; de Kleine et al., 2018), the five-item TIS (Bados et al., 2015), and the four-item TIS, in which the authors' goal was to avoid the risk of conceptual overlap with PD (Rocha-Rego et al., 2009).

In the present article, we aim to systematically and meta-analytically review the literature and investigate whether peritraumatic TI is associated with the development, symptom severity, and course of PTSD. Given that the literature reports significant sex/gender-related differences in PTSD, we also aim to examine through a meta-analysis whether the severity of TI experiences differs for males and females. Additionally, through a qualitative synthesis, we aim to identify the types of traumatic events more strongly related to TI. We hypothesize that a) TI is associated with increased risk for PTSD development, b) TI is associated with increased PTSD symptom severity, c) TI is associated with a negative effect on the course of PTSD in terms of poorer symptom recovery, d) TI is most often elicited in individuals who experience interpersonal violence compared to non-interpersonal violence, e) TI severity is higher for females. Understanding how TI reactions can influence psychopathological outcomes downstream, particularly PTSD, may provide indicators on how to enhance prevention strategies and minimize the likelihood of unfavorable treatment responses. Thus, it is necessary to first review the current literature and summarize and evaluate the evidence on the implications of TI on PTSD. To the best of our knowledge, this is the first systematic and meta-analytic review focused on the associations between TI and PTSD.

2. Methods

2.1. Systematic review

We retrieved articles for this systematic review from Embase, PubMed, PsycINFO, and Scopus with a publication date prior to October 10, 2022. Details of the protocol for this review were preregistered on Open Science Framework (https://osf.io/4xvuk). We used MeSH terms related to PTSD and traumatic events combined with peritraumatic reactions, e.g., tonic immobility, paralysis, catatonia, catalepsy, and freezing (see supplementary material, Parts 1 and 2, for entire search strategy). Two reviewers (BMC and ATD) screened the initial 250 records independently, resulting in a moderate interrater agreement (kappa=0.6). Thus, to avoid missing eligible articles, the two reviewers (BMC and ATD) screened all records separately and compared the results. Additionally, we hand-searched references of relevant articles on TI to identify potential missing studies in our systematic search. This systematic and meta-analytic review was conducted according to the updated guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021).

2.2. Inclusion and exclusion criteria

Articles eligible for this systematic review were those that investigated whether the occurrence of peritraumatic TI is associated with the development, symptom severity, and/or course of PTSD (including observational studies and intervention studies). In addition, studies that examined differences in TI prevalence according to trauma type were also eligible. All articles had to be written in English and published in

peer-reviewed journals prior to October 10, 2022. We excluded studies that investigated a) TI prevalence without analyzing which traumatic event(s) is (are) associated with TI occurrence; b) the association of TI with other psychiatric disorders than PTSD (e.g., depression, anxiety disorders); c) TI processes in laboratory settings; d) validation of scales.

2.3. Data extraction and quality assessment

One reviewer (BMC) extracted data from the selected articles, and three other reviewers (CH, MvZ, ATD) verified the extraction accuracy. Besides first author and year of publication, we extracted the following data from articles: sample size; sex (percentage of females); age range (with mean age if available); sample setting (i.e., community sample, clinical sample); study location (i.e., city and country); type(s) of the traumatic event(s); PTSD symptom severity assessment (with mean score and standard deviation (SD) if available), method for probable PTSD diagnosis, and/or questionnaires used to evaluate traumatic events; TI assessment (with mean score and SD if available); time elapsed since trauma; study objectives; study design; main outcomes and findings. For the meta-analysis, we extracted effect sizes of the relationship between TI and the development, symptom severity, and course of PTSD without covariates. Moreover, for the meta-analytic investigation of sex differences in TI severity, we extracted means and standard deviation (SD) of TI scores separately for males and females from studies that enrolled individuals of different sexes. We provide all data stratification for the meta-analyses as supplementary material (Part 4).

We contacted authors for papers that did not report all required data for calculating the effect size and/or that did not provide TI scores separately for sex, and requested additional data. Of the 11 studies whose authors we contacted requesting effect sizes for the relationship between TI and PTSD symptom severity, we obtained eight positive responses with the requested data. Authors of three studies responded that requested data were not available. Additionally, we contacted authors of 12 studies in which we could not find TI scores for males/females, from whom we received eight positive responses (four authors responded that data were unavailable).

The quality assessment of the selected studies was performed by two independent reviewers (BMC and ATD) using the Joanna Briggs Institute (JBI) Critical Appraisal checklist for Analytical Cross-Sectional studies (Moola et al., 2020). We rated studies based on eight items proposed by the JBI, thus obtaining a percentage score for the quality of each study (a higher percentage indicated better quality). Disagreements on the quality of the studies were resolved with the help of a third reviewer (CH, see supplementary material, Part 6, for the entire quality assessment).

2.4. Statistical analyses and moderators

We used R software with package *Metafor* for all analyses (Viechtbauer, 2010). The relationship between TI and PTSD symptom severity, PTSD development, and course of PTSD were determined by pooling effect sizes across studies. We standardized PTSD symptom severity effect sizes to Pearson's *r* correlation coefficient (a positive correlation would indicate a positive relationship between TI and PTSD symptom severity), and increased risk for development and course of PTSD to odds ratio (OR). To analyze TI severity and sex differences, we used the standardized mean difference to derive a Cohen's *d* value. Lastly, to investigate whether the nature of trauma is associated with TI, we performed a qualitative synthesis of the included articles.

We assessed heterogeneity between studies through random-effects models using Q index and I^2 statistic. We considered heterogeneity significant if I^2 was higher than 75%, as discussed in Higgins and Thompson (2002). If so, we performed moderation analyses with a meta-regression approach by fitting mixed-effect models to investigate which study-level characteristics accounted for heterogeneity. As literature reviews concluded that age and gender are associated with the onset and severity of PTSD (Brewin et al., 2000; Olff, 2017), we examined whether mean age and percentage of female-identifying individuals would have a moderating effect on the relationship between TI and PTSD. Additionally, literature reviews report that a) interviews and self-measure instruments may yield differences in PTSD diagnosis and severity (Swartzman et al., 2017), and b) defining methodological quality scores for eligible studies in meta-analyses may influence results when incorporated in moderator analyses (Protogerou & Hagger, 2020). Thus, we further explored heterogeneity using two other variables: PTSD assessment (interview versus self-report scale) and study quality ratings (using the percentage score provided by the JBI as a continuous variable).

Furthermore, as included studies may differ in terms of TIS versions applied, we grouped studies into two categories and performed an exploratory analysis to investigate a mediating effect: studies that measured the TI factor only versus studies that measured both the TI factor and the fear factor. Additionally, as included studies may have assessed peritraumatic TI experienced long before the individuals' study recruitment, and, thus, as suggested by previous evidence (Gower et al., 2022), subjected to memory bias, we used the time elapsed since trauma as a moderating variable in the analysis. As the number of studies reporting the time elapsed since trauma was small ($k = 7$), we grouped studies into two categories that would us give us power for the moderation analysis: studies where the trauma occurred up to one year before recruitment ($k = 4$) versus studies where trauma occurred outside the one-year period ($k = 3$).

We investigated publication bias visually inspecting the symmetry of the funnel plots. Also, we performed two different methods for an accurate investigation of publication bias: Kendall's tau and Egger's test (Begg & Mazumdar, 1994; Egger et al., 1997). In case of an indication of publication bias, we used Duval and Tweedie's trim-and-fill method to correct and adjust for publication bias because of missing studies (Duval & Tweedie, 2000). Furthermore, if the associations between TI and PTSD were statistically significant, we performed Rosenthal's and Rosenberg's fail-safe tests to assess the robustness of the results (Rosenberg, 2005; Rosenthal, 1979). Fail-safe tests are relevant because they offer an index of the stability of the obtained results. A fail-safe *N* suggests robustness if larger than $5k + 10$ (k, in this case, represents the number of included studies in the meta-analysis).

3. Results

3.1. Literature search

The complete study identification process is visualized in the PRISMA diagram (Fig. 1). Our search strategy identified $k = 2878$ records through Embase, PubMed, PsycINFO, and Scopus, of which $k = 1583$ were duplicates. Of the $k = 1295$ remaining records, we excluded $k = 711$ based on their titles, resulting in $k = 584$ records for further screening. We assessed the abstracts of the $k = 584$ records and excluded $k = 503$ based on their abstracts (see Fig. 1 for reasons). The remaining $k = 81$ full-text articles were assessed, of which $k = 26$ were included in the current review. Additionally, one eligible article was identified through reference list review. Thus, $k = 27$ articles met our criteria and were considered eligible for this systematic review.

3.2. Study characteristics

We present a description of the included studies in Table 1. Samples for the included studies ranged from $n = 29$–4781 individuals, and most studies ($k = 19$) had a sample of either a majority or the entirety of female-identified participants. Except for two studies that included adolescents, all other studies enrolled adults, with an age range of 18–93 years. Traumatic events assessed across samples were variable, but most traumatic experiences were related to interpersonal violence. Studies originated from North America ($k = 7$), Europe ($k = 10$), and Brazil

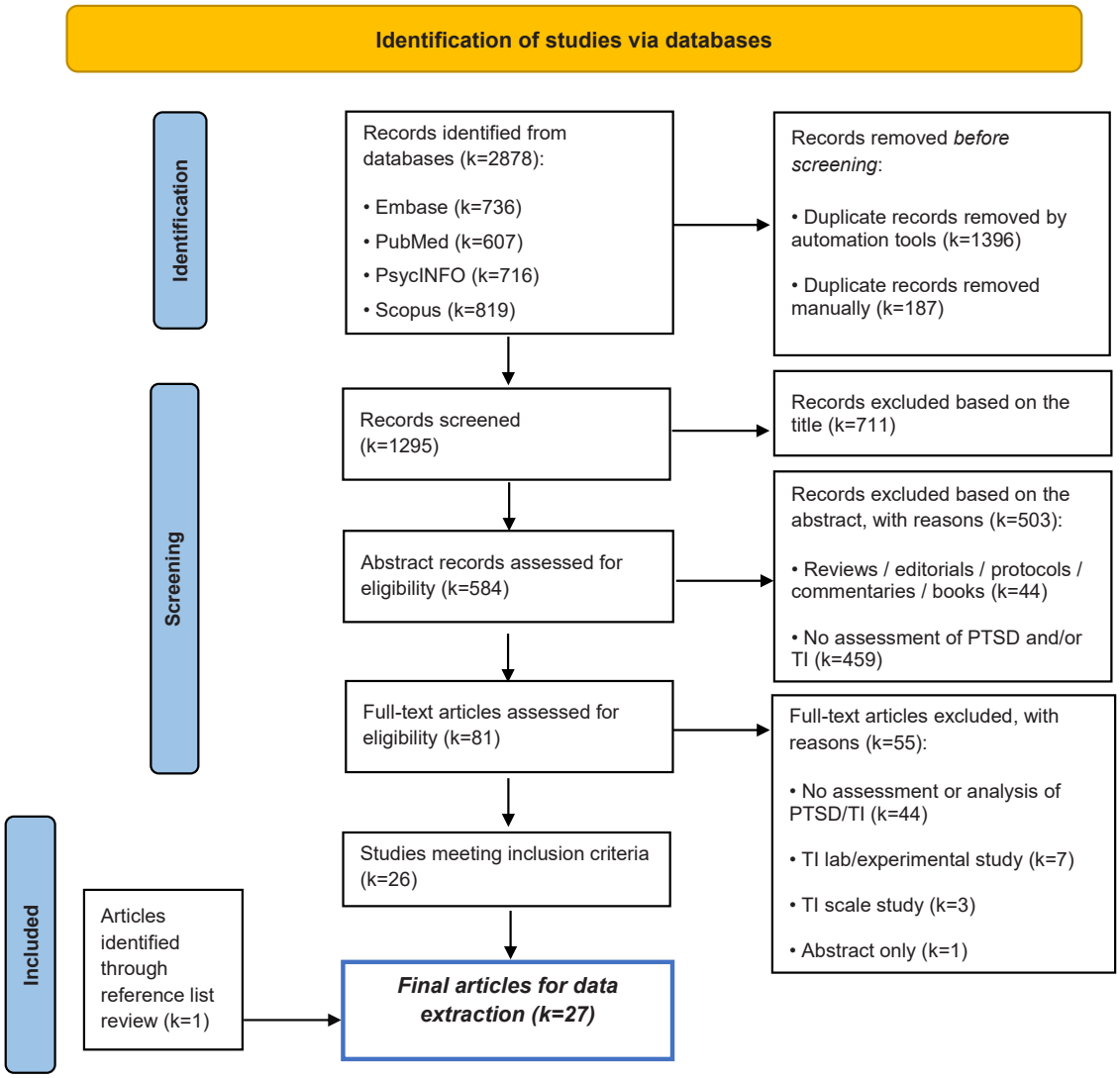

Fig. 1. – Flow diagram of the systematic review.

(k = 10). The most frequently used instrument to measure TI was the Tonic Immobility Scale (TIS, k = 25). Most studies (k = 10) applied a reduced number of items of the original 10-item validated TIS first used by Heidt and colleagues (2005). For a detailed explanation of TI measures in the literature, see supplementary material, Part 7.

3.3. Study objectives and outcomes/findings

We present information on the 27 eligible articles' objectives, outcomes, and findings regarding the associations between TI and PTSD, and TI occurrence related to the type of traumatic event in Table S1 (supplementary material, Part 3). We identified a large variety of objectives in our article selection. Most studies investigated the association between TI and PTSD symptom severity. However, some studies investigated TI in association with PTSD development, PTSD symptom cluster severity, types of traumatic events most associated with TI reactions, and the association of TI with PTSD treatment response and with individual sex. Most studies used a cross-sectional design (k = 23).

3.4. Tonic immobility and PTSD symptom severity

We pooled the effect sizes of 22 studies representing 9625 individuals investigating the association between TI and PTSD symptom severity. Fig. 2 shows the forest plot of the main analysis. We found an association between TI and PTSD symptom severity ($r = 0.39$, 95% CI: 0.34–0.44; $p < .0001$), which meets criteria for a moderate effect. There was significant heterogeneity between studies (Q (21) $= 133.26$, $p < .0001$; $I^2 = 84.24\%$). None of the moderators were significantly associated with the effect of TI on PSTD symptom severity (Table S2, supplementary material, Part 5). Additionally, fail-safe tests confirmed the robustness of our findings ($N_{Rosenberg}$ =18,356; $N_{Rosenthal}$ =12,074). Kendall's tau correlation coefficient did not suggest publication bias ($\tau = -0.05$, $p = .74$). However, visual inspection of the funnel plot showed asymmetry, and Egger's test indicated publication bias ($t = -2.62$, $p = .016$). Therefore, we applied Duval and Tweedie's trim-and-fill procedure to correct for publication bias. Fig. 3 shows the adjusted funnel plot for missing studies (estimate missing studies: $k = 7$). The correlation coefficient for the relationship between TI and PTSD symptom severity increased, and the effect remained statistically significant after adjusting for missing studies ($r = 0.44$, 95% CI: 0.39–0.48; $p < .0001$).

3.5. Tonic Immobility and increased risk of developing PTSD and influencing PTSD course

We found two studies investigating the relationship between TI and increased risk of PTSD development upon trauma exposure (Gama et al., 2022; Möller et al., 2017) and three studies investigating the

Table 1 –
Description of the included studies.

Reference	Sample size	Sex (% of female)	Age range (mean)	Sample setting & location	Study design	Type (s) of trauma	PTSD (mean score, SD) and/or traumatic events assessment	TI assessment (mean score, SD)	Time elapsed since trauma
Heidt et al. (2005)	80	Female (100%)	18–51 (27.13)	Undergraduate students (n = 39) and a clinical sample in Northeastern U.S. (n = 41)	Cross-sectional	Childhood sexual abuse	PDS (undergraduate students: 11.22, 8.53; inpatients: 33.08, 9.41) & LEQ	TIS-C (NR)	NR
Bados et al. (2008)	100	Male/ Female (87%)	NR (23.1)	College students in Barcelona, Spain	Cross-sectional	Five categories: a) suffering a serious accident; b) being the victim of an assault or physical aggression; c) suffering physical/ psychological or sexual abuse; d) receiving news of serious injury or violent or sudden death of a loved one; and e) other traumas	TEQ	TIS-A (exposed group: 17.09, 7.27)	NR
Bovin et al. (2008)	176	Female (100%)	19–39 (22.9)	Undergraduate students, U.S.	Cross-sectional	Sexual assault	PDS (10.19, 10.13) & SES	TIS-A (15.30, 8.12)	NR
Fiszman et al. (2008)	23	Male/ Female (39%)	NR (41.1)	Community sample in Brazil	Prospective	Armed robbery (83%)	PCL-C (Baseline: 66.2, 11.3; Follow-up: 57.6, 16.6) & SCID-IV	TIS-A (NR)	41 months (mean)
Abrams et al. (2009)	78	Male/ Female (78%)	NR (20.2)	Undergraduate students in Saskatchewan, Canada	Cross-sectional	Interpersonal trauma, accident-related trauma, death exposure, other	PCL-C (NR) & LTEC	TIQ (24.11, 10.75)	NR
Rocha-Rego et al. (2009)	32	Male/ Female (41%)	NR (41)	Community sample in Brazil	Cross-sectional	Armed robbery (n = 25), motor vehicle accident (n = 5), attempted rape (n = 1), burns (n = 1)	PCL-C (66, 10.6) & SCID-I	TIS-4 (12, 7.9)	27 months (mean)
Humphreys et al. (2010)	131	Female (100%)	20–45 (24)	Undergraduate students, U.S.	Cross-sectional	Childhood sexual abuse	PDS (11.06, 10.80) & LTEC	TIS-C (19.56, 8.43)	NR
Lima et al. (2010)	36	Male/ Female (47.2%)	NR (39.6 for males, 41.5 for females)	Community sample in Brazil	Prospective	Armed robbery (n = 28), motor vehicle accident (n = 5), sexual assault (n = 2), burn (n = 1)	PCL-C (66.9, 10.24)	TIS-4 (NR)	NR
Kunst et al. (2011)	125	Male/ Female (63.2%)	NR (40.82 for males, 48.34 for females)	Community sample in the Netherlands	Cross-sectional	Sexual assault (n = 19), moderate physical assaults (n = 34), thefts with violence (n = 40), other interpersonal violence (n = 25)	PSS-SR (14.47, 14.04)	TIS-3 (10.91, 6.28)	NR
Abrams et al. (2012)	75	Male/ Female (88%)	18–65 (31.49)	College students and community members in Saskatchewan, Canada	Cross-sectional	Sexual assault (n = 19), physical assault (n = 9), motor vehicle accident (n = 5), other accidents (n = 1), trauma involving death, e. g., unexpected death of a loved one; n = 17), and other (n = 24)	PCL-C (43.79, 14.91)	TIQ (8.38, 5.06)	NR
Portugal et al. (2012)	198	Male/ Female (80%)	18–52 (20.3)	Undergraduate students in Rio de Janeiro, Brazil	Cross-sectional	Death/loss of someone close, (n = 64), violent crime (n = 50), medical causes (n = 45), vehicle	PCL-C (29.7, 10.9) & THQ	TIS-4 (8.9, 6.9)	NR

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Table 1 – (*continued*)

Reference	Sample size	Sex (% of female)	Age range (mean)	Sample setting & location	Study design	Type (s) of trauma	PTSD (mean score, SD) and/or traumatic events assessment	TI assessment (mean score, SD)	Time elapsed since trauma
						accident (n = 17), child abuse (n = 5), domestic violence (n = 5), injury (n = 5), natural disaster (n = 2), other (n = 5)			
Bovin et al. (2014)	63	Female (100%)	19–52 (34.48)	Community sample, U.S.	Cross-sectional	Childhood sexual/physical abuse (68.3%), adult sexual/physical abuse (52.4%), motor vehicle accidents (36.5%), another life-threatening event (82.5%), witnessing or learning about death (79.4%), and being stalked (33.3%)	CAPS-IV (37.52, 28.32) & TLEQ	TIS-TI (22.96, 8.21)	NR
Bados et al. (2015)	273	Male/ Female (82.1%)	NR (23.1)	College students in Barcelona, Spain	Cross-sectional	Five categories: a) physical maltreatment in childhood/ adolescence, sexual abuse in childhood/ adolescence or physical maltreatment in adulthood (n = 42); b) non-sexual violent crime (n = 26); c) serious traffic accident or serious risk of losing one's life or of being severely injured (n = 42); d) receiving news of serious injury or violent or unexpected death of a loved one & other traumas (n = 112); e) witnessing a violent death or witnessing a serious accident (n = 51)	TEQ	TIS-5 (NR)	NR
Christiansen and Hansen (2015)	368	Male/ Female (61.1%)	20–65 (42.0)	Employees exposed to bank robbery in Denmark	Cross-sectional	Bank robbery and sexual trauma	HTQ (females: 26.77, 8.30; males: 22.54, 6.60)	TIS-4 (females: 8.76, 7.25; males: 5.53, 5.66)	6 months
Kalaf et al. (2015) & (2017)*	3231	Male/ Female (55.7%)	15–75 (NR)	Community sample in São Paulo & Rio de Janeiro, Brazil	Cross-sectional	Nineteen different types of traumatic events in the sample	CIDI 2.1	TIS-6 (9.17, SD: 9.70)	NR
Maia et al. (2015)	265 (baseline); 132 (follow-up)	Male (0%)	NR (23.3)	Police officers in a midwestern state in Brazil	Prospective	NR	PCL-5 (21.5, SD: 7.7) & CIHQ	TIS-4 (NR)	Less than one year (follow-up)
Van Buren and Weierich (2015)	46	Female (100%)	18–37 (22.11)	College students, U.S.	Cross-sectional	Childhood sexual abuse	PDS (12.26, 8.37)	TIS-C (18.26, 6.20)	NR
Hagenaars (2016)	4781	Male/ Female (54%)	16–93 (50.48)	Community sample in the Netherlands	Cross-sectional	Childhood sexual abuse (n = 122), childhood physical abuse (n = 110), childhood emotional abuse (n = 254), sexual violence (adult, n = 152),	PSS-SR (individuals with PTSD: 23.56, 7.70; trauma experienced but no PTSD: 7.53, 3.05) & NLETQ	TIS-TI (individuals with PTSD: 15.02, 8.38, trauma experienced but no PTSD: 8.50, 6.79)	NR

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Table 1 – (*continued*)

Reference	Sample size	Sex (% of female)	Age range (mean)	Sample setting & location	Study design	Type (s) of trauma	PTSD (mean score, SD) and/or traumatic events assessment	TI assessment (mean score, SD)	Time elapsed since trauma
						physical violence (adult, n = 234), serious accident (n = 286), disaster or fire (n = 66), life threatening illness (n = 417), war-related trauma (n = 436), other (n = 273)			
Möller et al. (2017)	Baseline: 298; Follow-up: 189	Female (100%)	17–59 (24)	Community sample in Stockholm, Sweden	Prospective	Rape	Baseline: PDS (NR) & SASRQ (NR). Follow-up: SASRQ (with TI: 98.5, NR) & SCID-I (PTSD module)	TIS-A (37.3, 14.6)	TI and ASD assessment: 19.1 days (mean). PTSD assessment: 6 months
de Kleine et al. (2018)	184	Male/ Female (69.6%)	NR (39.4)	Clinical sample in the Netherlands	Cross-sectional	Sexual abuse (n = 81), sudden (violent) death (n = 16), physical violence (n = 56), warzone experiences (n = 7), natural disaster/accident (n = 6) & other (n = 18)	PSS-SR (30.92, 8.23) & M.I.N.I	TIS-TI (during trauma: 26.71, 8.56; during re-experiencing: 24.33, 8.32)	More than five years (76.6%)
Hagenaars and Hagenaars (2020)	262	Male/ Female (64.9%)	18–86 (53.1)	Community sample in the Netherlands	Prospective	Childhood sexual abuse (n = 19), childhood physical abuse (n = 23), childhood emotional abuse (n = 52), sexual assault (n = 36), physical assault (n = 32), war-related trauma (n = 34), serious accident (n = 31), disaster or fire (n = 9), life-threatening illness (n = 46), other (e.g., violent, or sudden death of a loved one, armed burglary; n = 63)	NLETQ & PSS-SR (year one: 23.55, 7.88; year two: 15.80, 10.18)	TIS-TI (year one: 14.91, 8.18)	NR
Magalhaes et al. (2021)	736	Male/ Female (65.5%)	NA (14.48)	Ninth grade school students in São Gonçalo, RJ, Brazil	Cross-sectional	Most common: hearing about a violent death/ serious injury of a loved one (27.2%), seeing a dead body in your town (16.2%) and being in a place where an armed conflict was going on around the individual (12.6%)	UCLA PTSD Reaction Index (34.16, 12.31)	TIS-4 (7.08, 6.47)	NR
Massazza et al. (2021)	308	Male/ Female (59%)	18–81 (47.65)	Community sample in Amatrice and surroundings, Lazio, Italy	Cross-sectional	Earthquakes	PCL-5 (24.82, 18.19)	TIS-A (23.78, 15.23)	15–20 months
deMello et al. (2022)	29	Female (100%)	18–45 (26.3)	Community sample in São Paulo, Brazil	Cross-sectional	Sexual assault	CAPS-5 (37.8, 3.7) & M.I.N.I	TIS-4 (NR)	1–6 months
Dokkedahl et al. (2022)	150	Female (100%)	NR (34.6)	Women's shelters, Denmark	Cross-sectional	Intimate partner violence (physical, psychological, and/ or sexual violence)	PMWI & ICD-11 PTSD (15.45, 5.35)	TIS-4 (12.85, 4.92)	NR
Gama et al. (2022)	1001	Male/ Female (76.4%)	19–83 (40.4)	Health workers in Brazil	Cross-sectional	Traumatic events related to Covid-19	PCL-5 (25.3, 17.0) & Covid-19 Index Trauma	TIS-6 (14.8, 10.2)	Past few months

Note. NR: Not reported; ASD: Acute stress disorder; CAPS-IV: Clinician-Administered PTSD Scale for DSM-IV; CAPS-5: Clinician-Administered PTSD Scale for DSM-5; CIDI 2.1: Composite International Diagnostic Interview; CIHQ: Critical Incident History Questionnaire; HTQ: The Harvard Trauma Questionnaire; ICD: International Classification Disease; M.I.N.I: Mini-International Neuropsychiatric Interview; NLETQ: Negative Life Events and Trauma Questionnaire; LEQ: Life Experiences Questionnaire; LTEC: Lifetime Traumatic Events Checklist; PCL-C: Posttraumatic Stress Disorder Checklist - Civilian Version; PCL-5: Posttraumatic Stress Disorder Checklist for DSM-5; PDS: Posttraumatic Stress Diagnostic Scale; PMWI: The Psychological Maltreatment of Women Inventory; PSS-SR: PTSD Symptom Scale - Self-Report version; SASRQ: Stanford Acute Stress Reaction Questionnaire; SCID-IV: Structured Clinical Interview for DSM-IV; SCID-I: Structured Clinical Interview for DSM-IV Axis I Disorders; SES: Sexual Experiences Survey; TEQ: Traumatic Events Questionnaire; TIQ: Tonic Immobility Questionnaire; TIS-A: Tonic Immobility Scale – Adult Form (ten items); TIS-C: Tonic Immobility Scale – Child Form (ten Items); TIS-TI: Tonic Immobility Scale – Tonic Immobility Factor (seven items); TIS-6: Tonic Immobility Scale (six items); TIS-5: Tonic Immobility Scale (five items); TIS-4: Tonic Immobility Scale (four items); TIS-3: Tonic Immobility Scale (three items), THQ: Trauma History Questionnaire; TLEQ: Traumatic Life Events Questionnaire; UCLA PTSD Reaction Index: The University of California at Los Angeles Posttraumatic Stress Disorder Reaction Index. *Two studies with the same sample

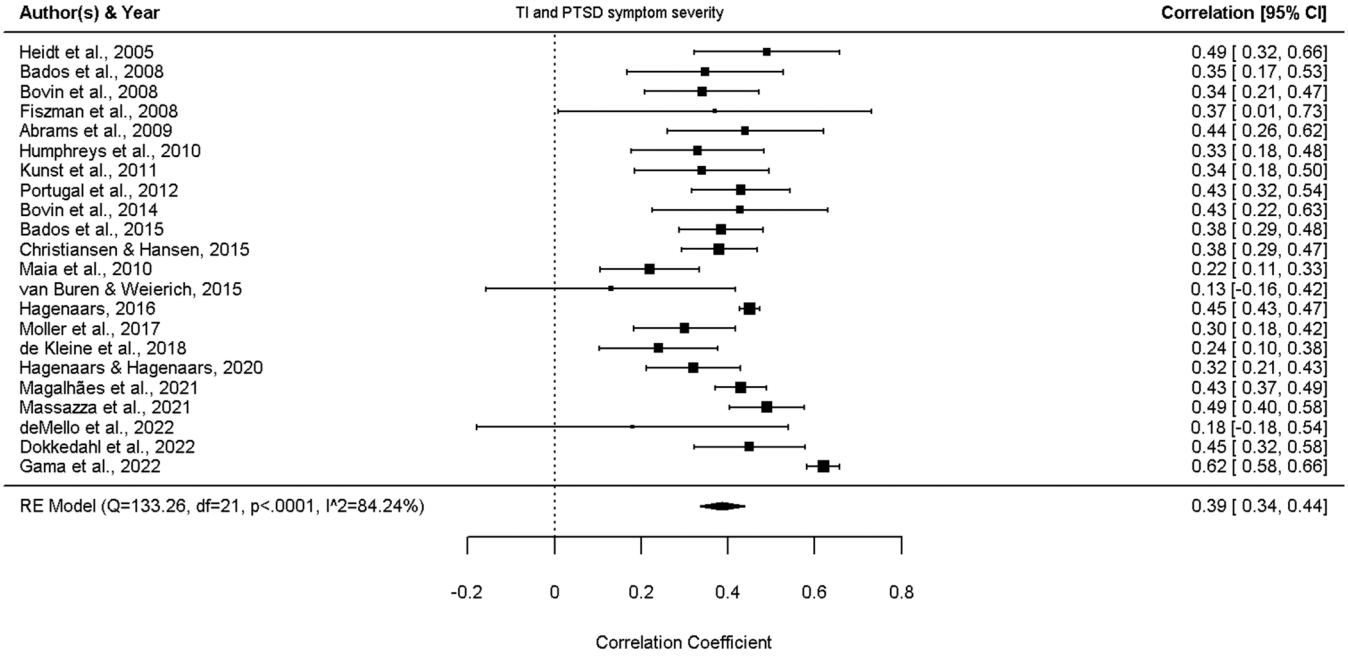

Fig. 2. Forest plot with Pearson's Correlation coefficient (*r*) between tonic immobility and PTSD symptom severity.

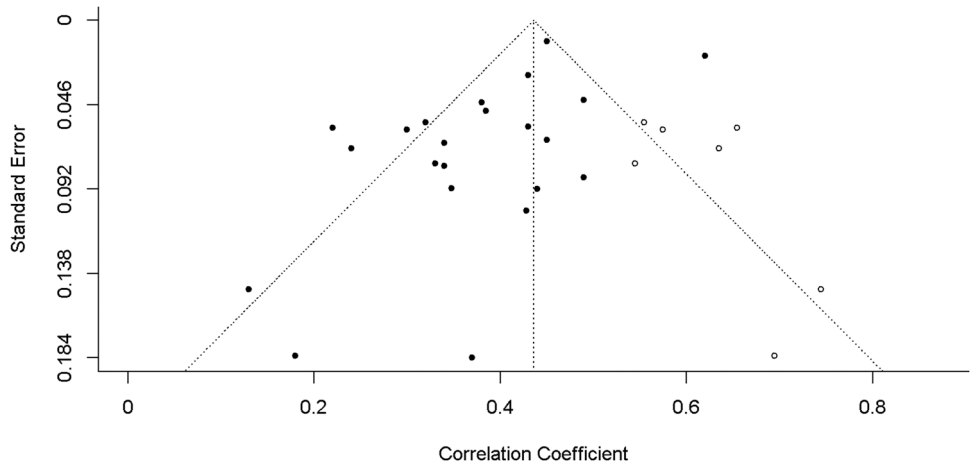

Fig. 3. Adjusted funnel plot for missing studies (k = 7) with Pearson's correlation coefficient (*r*) between tonic immobility and PTSD symptom severity.

relationship between TI and PTSD course in patients (Fiszman et al., 2008; Hagenaars & Hagenaars, 2020; Lima et al., 2010). Given the small number of effect sizes, we could not perform a meta-analysis of the relationship between TI and risk for PTSD development and course. However, results from our systematic review suggest that the evidence supports the relationship between TI and the development and negative effect on the course of PTSD. Gama et al. (2022) found that TI severity was associated with increased risk in presenting with a subsequent PTSD diagnosis (OR: 9.09, 95% CI: 5.24–15.79, $p < .01$). Möller et al. (2017) conducted the only study that assessed TI shortly after the traumatic event (mean: 19 days), showing that the prevalence of a PTSD diagnosis six months after trauma was almost three times higher for those who experienced TI compared to those who did not (OR: 2.75, 95% CI: 1.50–5.03, $p < .01$). With response to PTSD course, Fiszman et al.

(2008) and Lima et al. (2010) measured whether TI is longitudinally associated with poor pharmacological treatment response for patients with PTSD. Both studies concluded that TI may hinder treatment success in PTSD. In another longitudinal study with a patient sample enrolled outside an explicit treatment context, TI was a stronger predictor of poor PTSD recovery than other peritraumatic responses (Hagenaars & Hagenaars, 2020).

3.6. Tonic immobility severity and sex differences

We included ten studies for the meta-analysis of TI severity differences between females (n = 4127) and males (n = 2388). We compared TI severity scores (means and SD) between females and males across studies that enrolled individuals of both sexes. Fig. 4 shows the forest plot for the analysis. We found that TI severity was higher among females compared to males. The standardized mean difference for the analysis was Cohen's $d = 0.37$ (95% CI: 0.25–0.48; $p < .0001$), which meets criteria for a small effect size. Heterogeneity between studies was moderate according to I^2 statistics ($Q(9) = 21.07$, $p = .012$; $I^2 = 63.70\%$). As heterogeneity analysis yielded an I^2 value lower than 75%, we did not analyze the effects of potential moderators. Furthermore, visual inspection of the funnel plot showed minor asymmetry (see supplementary material, Fig. S1), but we found no indication of publication bias using Kendall's tau ($\tau = -0.20$, $p = .48$) and Eggar's test ($t = -0.84$, $p = .43$). Fail-safe tests confirmed the robustness of our results ($N_{Rosenberg} = 552$; $N_{Rosenthal} = 468$).

3.7. Tonic Immobility and the nature of trauma

Seven studies in our systematic review investigated whether the nature of trauma had an impact on TI. Our qualitative synthesis suggests TI is more often elicited when experiencing interpersonal violence compared to non-interpersonal violence. Although Abrams et al. (2009) and Bados et al. (2008) found TI to be unrelated to type of traumatic event, these studies had small samples (n = 78 and 68 trauma-exposed individuals, respectively) compared to studies that enrolled larger samples of over three thousand participants. These studies with larger samples found TI to be more strongly associated with sexual trauma in childhood and adulthood, emotional abuse, and war-related trauma compared to other types of traumatic events (Hagenaars, 2016; Kalaf et al., 2017). Studies also corroborated the higher prevalence of TI in survivors of interpersonal violence with more modest sample sizes (Bados et al., 2015), one of which also found TI to be more associated with physical assault than other types of trauma (Hagenaars & Hagenaars, 2020).

4. Discussion

In the present study, we aimed to investigate whether the literature supports the association between the occurrence of TI and the development, symptoms, and course of PTSD. Our meta-analysis indicates a significant association between TI and PTSD symptom severity with a moderate effect size. Funnel visual inspection and Egger's test indicated the presence of publication bias. After correcting for publication bias, the correlation coefficient increased, and results remained significant. The effect of TI on PTSD symptom severity could not be explained by studies' characteristics, as none of the analyzed moderators reached statistically significant levels. Thus, the current state of the evidence supports our hypothesis that the occurrence of TI is associated with PTSD symptom severity.

Re-experiencing the traumatic event is a core diagnostic criterion of PTSD. As awareness is preserved during TI, it may enhance the vividness of traumatic memories and recollection of peritraumatic details, contributing to increased PTSD symptom severity (Bovin et al., 2014; Hagenaars et al., 2008; Volchan et al., 2011). Interestingly, experimental research has suggested that the loss of control attributed to TI reactions is associated with increased vulnerability to developing intrusive memories (Hagenaars & Putman, 2011). Moreover, although involuntary, the motionless state experienced during TI prevents individuals from being able to react (Bovin et al., 2014; Gbahabo & Duma, 2021). Thus, it is plausible that raising posttraumatic rumination of self-critical passivity and concern of judgmental reactions from others for not "resisting" may be detrimental for PTSD symptom recovery (Marx et al., 2008).

Our systematic review identified few studies that investigate whether there is a relationship between TI and the development or course of PTSD. Due to the limited number of published studies, we could not perform a meta-analysis. Although studies suggest that TI may be a significant predictor of the development of PTSD (Bovin et al., 2008; Gama et al., 2022; Kalaf et al., 2015), there is limited evidence of prospective investigations to assess whether TI is associated with increased risk of subsequently developing PTSD and longer duration of

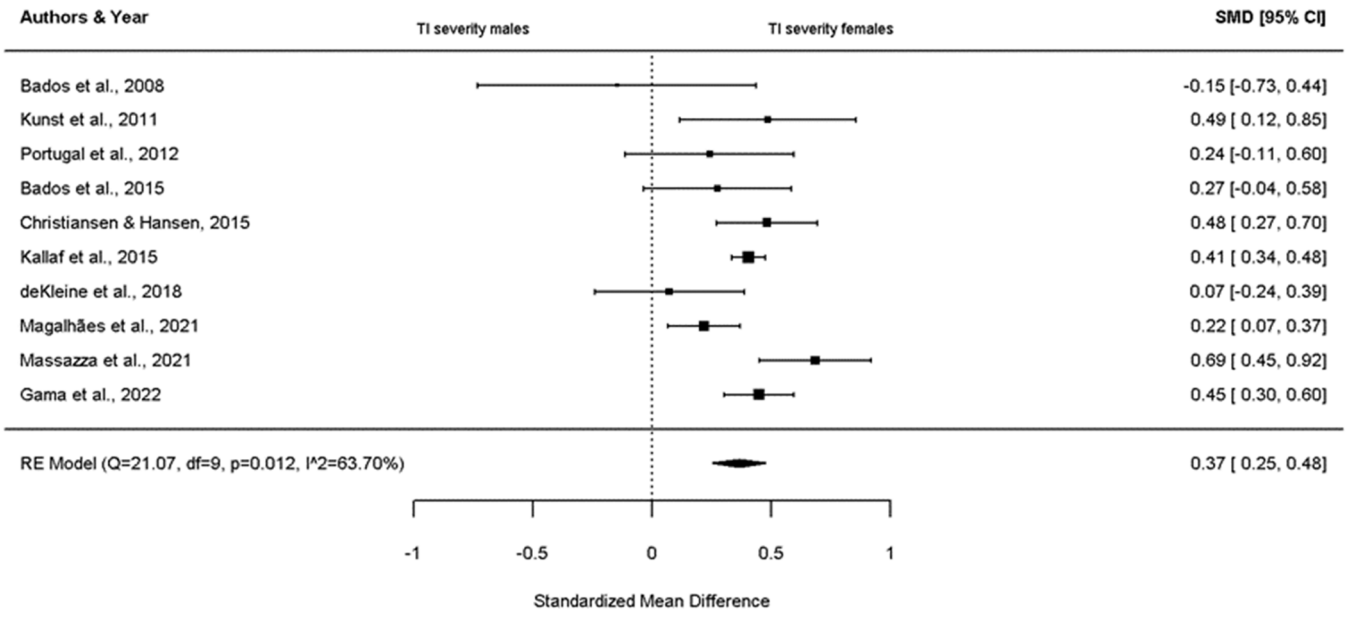

Fig. 4. Forest plot with the standardized mean difference for tonic immobility severity for males and females.

the disorder. The longitudinal findings that TI may worsen the course of PTSD and hinder treatment success are consistent (Fiszman et al., 2008; Hagenaars & Hagenaars, 2020; Lima et al., 2010) but limited due to the modest number of published studies. The existing evidence suggests that TI is associated with the development and an unfavorable course of PTSD, but our hypotheses cannot be meta-analytically investigated until further studies are published.

Furthermore, through a systematic review, we examined whether the nature of trauma influences the occurrence of TI. Research supports our hypothesis that TI is more likely to be elicited in a traumatic event involving interpersonal violence. Studies enrolled survivors of a significant variety of traumatic events and suggested that traumatic events associated with interpersonal violence may be experienced as inherently more threatening (Kalaf et al., 2015). This may be particularly true in sexual trauma, when perceived inescapability and extreme fear, the two necessary components triggering TI are present (Bovin et al., 2008; Bovin et al., 2014; Marx et al., 2008). In addition, evidence implicates the severity of sexual trauma, such as completed rape or continuous sexual abuse as a predictor of TI reaction (Bovin et al., 2008; Heidt et al., 2005; Humphreys et al., 2010). If so, as previous studies suggested, TI may function as a proxy indicator of the perceived level of threat experienced during the traumatic event (Abrams et al., 2012; Zoellner, 2008).

Moreover, although an investigation of the prevalence of TI reactions was not an objective of the present systematic review, selected studies reported that TI is a common peritraumatic response, ranging from 25.3% to 69.8% of individuals reporting a traumatic experience (Hagenaars, 2016; Möller et al., 2017). Of note, the reviewed literature suggests that many different types of traumatic event can elicit TI, including events unrelated to interpersonal violence and events that do not necessarily involve an immediate physical life-threatening situation, e.g., sudden loss of a loved one or high exposure to Covid-19 (Abrams et al., 2009; Bados et al., 2008; Gama et al., 2022; Kalaf et al., 2017; Massazza et al., 2021). These findings broaden knowledge from initial research that theorized TI as a peritraumatic reaction during sexual assault victimization (Suarez & Gallup, 1979).

An additional aim of our study was to investigate sex differences in TI severity. Although the magnitude of the difference was small, our meta-analysis indicates that females report more severe TI than males (Cohen's $d = 0.37$). Heterogeneity between studies was moderate, limiting investigation of potential moderators within this association. Thus, it remains unclear whether these observed sex differences are due to different mechanisms underlying TI attributable to sex. Nevertheless, sex differences in the subjective experience of TI may be one variable that may account for higher PTSD prevalence and severity among females, an issue that we urge future studies to address.

We identified several important limitations in the literature. Research findings are mostly retrospective, and peritraumatic TI assessment is possibly subjected to memory bias, limiting the investigation of causal relationships (Möller et al., 2017). This lack of prospective evidence on how TI relates to PTSD development and progression should fuel more research. Additionally, it is important to underscore that evoking peritraumatic recollections after a long period may increase the risk of bias, especially when adults recall events that occurred in childhood, as was the case in some of the included studies (e.g., Heidt et al., 2005; Humphreys et al., 2010; Van Buren & Weierich, 2015). It may be difficult for individuals with PTSD to provide accurate information on past behavioral and emotional states; therefore, peritraumatic responses should preferably be assessed in the aftermath of trauma (Candel & Merckelbach, 2004; Möller et al., 2017). We attempted to use the time frame as a moderator of the effect of TI on PTSD symptom severity. However, few included studies assessed time elapsed since trauma during TI and PTSD assessment or used it as a control variable or as a moderator of the association between TI and PTSD symptom severity, limiting our moderation analysis. Furthermore, deciding which items of the TIS should be used in research is conflicting, as studies used four, five, six, seven or the original ten items of the TIS dimensional aspects. Our analysis showed no moderating value of the TIS factors on PTSD symptoms severity, but some researchers argued that favoring a shortened version of the TIS (i.e., using its specific motor items) and excluding the specific items on cognition and fear may avoid a conceptual overlap with PD (Lima et al., 2010; Portugal et al., 2012; Reichenheim et al., 2014; Rocha-Rego et al., 2009). Theoretically, TI and PD are two separate constructs, reflected in intact or even enhanced cognition for TI (e.g., heightened awareness) versus impairment for PD (deMello et al., 2022; Gallup et al., 1980; Hagenaars & Hagenaars, 2020). TI and PD may be interrelated peritraumatic responses; however, it is unclear whether current research findings on peritraumatic responses are sufficient to conclusively separate or combine the two constructs (Abrams et al., 2012; Beutler et al., 2022).

In summary, our systematic and meta-analytic literature review retrieved 27 eligible articles investigating whether TI is associated with the development, severity, and course of PTSD and whether the nature of the traumatic event is associated with TI reactions. The current state of the research confirmed our hypotheses that there is an association between TI and PTSD symptom severity, that TI reaction is more severe among females, and that TI is more often elicited when experiencing interpersonal violence. However, evidence on TI as a peritraumatic response influencing the increased risk of PTSD development and a negative effect on the course of the disorder is limited to perform a meta-analysis, and more prospective investigation is needed to address this literature gap.

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Declaration of Competing Interest

None.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.janxdis.2023.102730.

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