

BMJ Open What work-related exposures are associated with post-traumatic stress disorder? A systematic review with meta-analysis

Pieter Coenen ,¹ Henk F van der Molen ²

To cite: Coenen P, van der Molen HF. What work-related exposures are associated with post-traumatic stress disorder? A systematic review with meta-analysis. *BMJ Open* 2021;11:e049651. doi:10.1136/bmjopen-2021-049651

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online. (<http://dx.doi.org/10.1136/bmjopen-2021-049651>).

Received 31 January 2021
Accepted 09 August 2021



© Author(s) (or their employer(s)) 2021. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

¹Department of Public and Occupational Health, Amsterdam Public Health Research Institute, Amsterdam UMC, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands
²Department of Public and Occupational Health, Netherlands Center for Occupational Diseases, Amsterdam Public Health Research Institute, Amsterdam UMC, University of Amsterdam, Amsterdam, The Netherlands

Correspondence to
Dr Henk F van der Molen;
h.f.vandermolen@amsterdamumc.nl

ABSTRACT

Objectives Although there is evidence that work-related exposures cause post-traumatic stress disorder (PTSD), there are few quantitative studies assessing the degree to which these factors contribute to PTSD. This systematic review with meta-analysis identified work-related exposures associated with PTSD, and quantified their contribution to this disorder.

Methods We searched Medline, PsycINFO, Embase, PILOTS and Web of Science (2005–10 September 2019) for longitudinal studies on work-related exposures and PTSD. We described included articles, and conducted meta-analyses for exposures with sufficient homogeneous information. We performed subgroup analyses for risk of bias, study design and PTSD ascertainment. We assessed evidence quality using Grades of Recommendations, Assessment, Development and Evaluation, and estimated population attributable fractions.

Results After screening 8590 records, we selected 33 studies (n=5 719 236). From what was moderate quality evidence at best, we identified various work-related exposures that were associated with PTSD, mainly involving individuals in the military and first responder (eg, police or fire brigade) occupations. These exposures included the number of army deployments (OR: 1.15 (95% CI 1.14 to 1.16)), combat exposure (OR 1.89 (95% CI 1.46 to 2.45)), army deployment (OR 1.79 (95% CI 1.45 to 2.21)) and confrontation with death (OR 1.63 (95% CI 1.41 to 1.90)). Effects were robust across subgroups and exposures attributed modestly (7%–34%) to PTSD. We identified additional exposures in other occupations, including life threats, being present during an attack, and hearing about a colleague's trauma.

Conclusions We identified various work-related exposures associated with PTSD and quantified their contribution. While exposure assessment, PTSD ascertainment and inconsistency may have biased our findings, our data are of importance for development of preventive interventions and occupational health guidelines.

BACKGROUND

Post-traumatic stress disorder (PTSD) can be triggered when individuals experience or witness traumatic events. PTSD has been a clinical diagnosis since 1980, when the

Strengths and limitations of this study

- The strengths of this review are the systematic methods, including the a priori registered protocol, a thorough meta-analysis with sensitivity analyses, estimation of population attributable fractions and the assessment of evidential quality with Grades of Recommendations, Assessment, Development and Evaluation.
- Reported studies bear sources of heterogeneity and possible bias, for example, in the ascertainment of post-traumatic stress disorders (which was not always clinically diagnosed but sometimes based on self-reports).
- The external validity of our findings is limited as the majority of the studies in our review were based on armed forces, first responders and other male dominated occupations, and mainly from Western countries.
- Evidence reported in our review was moderate quality at best, among other elements, due to risk of bias regarding participation (ie, selection bias), attrition and misclassification.

third edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM) was published.¹ The most recent DSM-5² states that PTSD results from exposure to severely traumatic event(s), while exhibiting a pattern of symptoms characterised by intrusion, avoidance, negative moods and cognitions, arousal and reactivity. A diagnosis of PTSD also involves duration and functional impairment criteria, and the patient's symptoms should be exclusive (ie, not caused by drugs or other illnesses). Estimates of PTSD prevalence among the general population differ widely. For example, lifetime PTSD prevalence ranged from 6% to 9% in USA and Canadian samples, while prevalence rates in Australian samples range from 1% to 2%.³ The substantial differences between individual studies could result from different ways in which PTSD was ascertained, varying from

any type of clinical diagnosis, to self-reports of DSM-5 criteria and PTSD symptoms assessed as probable PTSD.

PTSD can have a major impact on individuals and society as a whole, as it is associated with mental comorbidities,⁴ substance abuse⁵ and suicide.⁶ PTSD is particularly prevalent among certain occupational groups, such as police officers, firefighters, medical workers and military personnel, all of whom can experience events that might trigger PTSD.^{7,8} One particular systematic review showed that the prevalence of PTSD in military veterans and other high-risk occupational groups can be almost twice as high as among the general population.⁸ Another more recent review identified a number of occupational groups, including healthcare workers, police officers, prison workers and emergency personnel, with an increased risk of PTSD.⁹ Also, various specific work-related exposures (ie, exposures to situations or conditions at work that may have an effect on PTSD) and their association with PTSD have been reported.⁷ This included traumatic events experienced by military personnel and first responders (eg, police officers or fire fighters). The latter review also identified journalists, healthcare workers or individuals in other occupations who are exposed to traumatic events or the aftermath thereof.⁷

Despite this evidence, the association of work-related exposures with PTSD has not yet been quantified in a meta-analysis. Such knowledge is of importance to answer questions regarding work-related causation and prevention, as a prelude to developing interventions. With regard to prevention, we need to quantify the contribution of work-related exposures in the onset of PTSD.¹⁰ Such data could be used to formulate clinically relevant exposure threshold limits, as has been done with other disorders.^{11,12} It could also be of use in occupational health guidelines, as many countries provide financial compensation for individuals diagnosed with an occupational disease.

In this study, our aim was to (1) identify the work-related exposures associated with the onset of PTSD and (2) quantify the extent to which such exposures contribute to this disorder. Evidence on the contribution of work-related factors to PTSD could be used to facilitate decisions in reporting schemes. It could also help to identify and prioritise preventive interventions against those exposures with the strongest effect, in terms of triggering PTSD.

METHODS

The protocol for this systematic review with meta-analysis was registered in PROSPERO¹³ a priori. The review itself was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement guidelines.¹⁴

Searches

The Medline, PsycINFO, Embase, PILOTS and Web of Science databases were systematically searched

for material published from 2005 (January) to 2019 (September 10). This was an arbitrarily chosen period on the basis of changes in people's exposure to work-related traumatic events and changes in the definition of PTSD over time.² The search strategy consisted of a combination of controlled search terms (eg, Medical Subject Headings) and free-text words used to specify search terms related to: (1) PTSD (2) exposure and (3) work. A methodological filter was used to select longitudinal studies (prospective, retrospective or case-control), studies published in English, and those involving human participants only. The search strategy used is described in detail in online supplemental file 1. We validated this search with various key references, to avoid term bias. In addition to the database search, we conducted snowball searches for additional studies. These were based on citation tracking (forwards and backwards) from the articles and reviews retrieved in our electronic search. We also conducted scoping searches for key researchers on this topic, and used ResearchGate profiles to identify relevant records and projects (including unpublished projects). Outcome articles were compared with potential protocol papers, to assess selective reporting.

Inclusion and exclusion criteria

Two reviewers, working independently of one another, used Rayyan (an online tool: <https://rayyan.qcri.org/>) to screen for eligible references. The full texts of any such references (whose eligibility was based on the screening title and abstract) were retrieved for further screening. Any conflicts were resolved during a consensus meeting. We included studies on the association between any work-related exposure and the onset of PTSD (acute or delayed) in paid workers of working age (aged 18–65). Any studies that described work-related exposures in terms of work demands or other occupational factors were eligible for inclusion. However, studies in which exposures were related to job title or work title only were excluded. Studies were included if there was an actual diagnosis of PTSD (either using checklists with defined cut-off values or clinical criteria, eg, using DSM criteria² and/or coded according to the International Classification of Disorders-9-CM 309.81-). Studies in which PTSD was assessed by means of self-reports only (not using any criteria) were excluded. We excluded any studies into the persistence or growth of PTSD. Those studies in which the exposure–outcome association was quantified, for example, in terms of effect sizes such as a HR, relative risk (RR) or OR, were included. We restricted ourselves to original articles, in English or Dutch, published in peer-reviewed scientific journals from 2005 onwards. Studies with a prospective, retrospective or case-control longitudinal design were included, while cross-sectional studies were excluded, to be able to monitor the time sequence between exposure and the PTSD onset, in which the assessments of exposure precede the actual onset of the disorder. The above-mentioned set of criteria were finalised after a pilot screening of 300 references.

Data extraction and risk of bias assessment

Two reviewers, working independently of one another, extracted data and assessed risk of bias from each of the eligible articles. Any conflicts were resolved during a consensus meeting. We extracted first author and year of publication, study name and design, sample (country, occupational group, age and sex), exposure assessment, PTSD ascertainment and effect size. Where it was not possible to retrieve sufficient information from the published articles, additional data were requested from study researchers.

Risk of bias was assessed using the 'Quality in Prognosis Studies' tool,¹⁵ with criteria related to study participation, attrition, prognostic factor (ie, exposure) measurements, outcomes, confounding and statistical analysis. Here, we attributed a low risk of bias regarding attrition to studies with a >80% participant retention.

Data analysis

The included articles were described in terms of extracted data and risk of bias. Work-related exposures were categorised according to the DSM-5 criteria for PTSD stressors⁹: (1) direct exposure to the trauma, (2) witnessing a trauma, (3) hearing about a colleague/coworkers (adapted to work context) was/were exposed to a trauma or (4) indirect exposure to aversive details of a trauma (eg, first responders and medics).

Where sufficient clinically and methodologically homogeneous information were available, a quantitative meta-analysis was conducted to determine a pooled effect size for the association of each exposure with PTSD. Review Manager (RevMan V.5) was used for the meta-analyses, and to generate forest and funnel plots. The latter were used to assess publication bias, through visual inspection. According to the Cochrane collaboration handbook, funnel plots were only generated for exposures with effect sizes from ≥ 10 studies.¹⁶ Most of the exposure–outcome associations featured statistical heterogeneity ($I^2 > 75\%$), so random-effects estimates were adopted for statistical pooling. We assumed that the interpretation of effect estimates (eg, HR and OR) was consistent, and we estimated pooled OR with 95% CI. We adopted the OR, as this was the most frequently reported effect size in the articles found (being reported in 32 articles, whereas two articles reported HRs and three articles reported RRs).

When more than one article reported on the same study, information from just one of these articles was used for analyses, using effect sizes from the article with the shortest follow-up duration (with a latency time of at least 4 weeks) to ensure that the work-related exposure of interest is indeed the most likely cause of PTSD. Wherever possible, we used information from fully adjusted models and we did not consider subgroups (eg, sex differences). Population attributable fractions (PAFs) were estimated¹⁷ to assess the extent to which work-related exposures contributed to the development of PTSD. Here, the proportion of workers exposed to the exposure of interest

(P_e) were multiplied by the attributable proportion in the exposed workers: $P_e(OR-1)/(1+P_e(OR-1))$.

In line with our registered protocol,¹³ subgroup analyses were based on the risk of bias (with a cut-off score of 60% for the risk of bias scale summary score, to obtain two subgroups), on the study design (prospective vs retrospective) and on PTSD ascertainment (clinically diagnosed PTSD vs probable PTSD). In contrast to the protocol that we registered a priori,¹³ we were unable to compare other characteristics of PTSD (ie, acute vs delayed) due to limited available data. Any information that could not be qualitatively analysed was described narratively.

Strength of evidence

The strength of the evidence was assessed using the Grades of Recommendations, Assessment, Development and Evaluation (GRADE) framework.¹⁸ Four quality levels were distinguished: high, moderate, low and very low. Our starting point for evidence grading was 'moderate', which has previously been proposed for use in the assessment of prognostic factors.¹⁹ Various study limitations could have detracted from the strength of the evidence (if the majority of the studies scored <60% on the risk of bias scale), as could inconsistency ($I^2 > 50\%$), indirectness, imprecision (95% CI boundaries are <1 and >2) and publication bias (based on the funnel plots). Study findings with moderate or large effect sizes (ie, lower limit of 95% CI OR >2.0) or an exposure–response gradient could boost the quality of the evidence.

Patient and public involvement

There was no patient or public involvement in designing and conducting this study.

RESULTS

Study selection

The study selection procedure is described in figure 1. We identified 14 529 records during database searches. After discarding duplicates, we screened the remaining 8590 records on title and abstract. Of these, we assessed 107 full-text articles and excluded 65 for various reasons (see online supplemental file 2 for more details). As no additional articles were found during snowball and scoping searches, 42 articles from 33 studies were described in this review.^{20–61}

Study description and methodological quality/risk of bias

Online supplemental file 3 contains the extracted data, and risk of bias assessment is shown in online supplemental files 4 and 5. The 33 included studies provided data on $n=5\,719\,236$ participants, ranging from $n=19$ to $n=2\,549\,949$ participants per study. Eighteen studies were from the USA, four were from the UK, two were from Denmark and two others from Japan. There was one study from each of the following countries: Israel, The Netherlands, Germany, Portugal, Italy, Norway and Korea. The majority of the studies ($N=21$) involved participants from

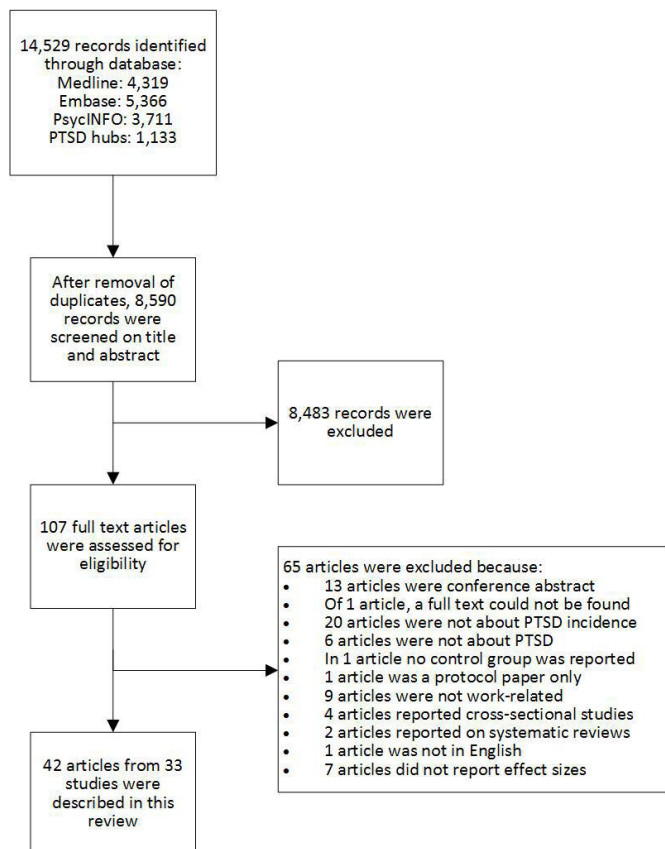


Figure 1 Flow chart depicting the search for literature. PTSD, post-traumatic stress disorder.

armed forces. Five studies featured first responders who had attended the scene of a disaster, three focused on healthcare workers, two on employers at the scene of a disaster, one on bank workers and one on public transport workers.

Four studies reported no details of sex, five studies only used male participants, and 17 used samples in which the majority of participants were male ($\leq 20\%$ females). In only seven studies, did female participants make up a reasonable proportion ($>20\%$) of the study sample. Twenty-eight studies reported exposures obtained from self-reports, 12 studies used deployment administration databases and 2 studies were based on a combination of these two measurements. Baseline exposure assessment was carried out for the period 1983–2012. Twenty-five articles assessed PTSD (by clinical diagnosis) while the remaining 17 articles assessed probable PTSD/PTSD symptoms (by self-reports using predefined (eg, DSM-5) criteria). The weighted average for PTSD prevalence during in the follow-up periods was 7.3%, while individual study prevalence ranged from 1.0% to 70.5%. The average prevalence for diagnosed cases of PTSD was slightly higher (7.3%) than for probable PTSD (6.4%).

Twenty-five studies were prospective studies and eight were retrospective studies. On average, methodological quality was 62% (SD:19%), ranging from 25% to 100%. Most articles showed a low risk of bias on analysis/reporting (N=37) and confounding (N=25). Less than

half of the articles showed a low risk of bias on participation selection (N=11), attrition (N=9), prognostic factor (exposure) assessment (N=9) and outcome (PTSD) ascertainment (N=13).

Work-related exposures

Each of the exposure–outcome associations presented have been described and categorised according to the DSM-5 criteria for PTSD stressors²: (1) direct exposure, (2) witnessing a trauma, (3) hearing that a colleague or coworker was exposed to a trauma or (4) indirect exposure to aversive details of a trauma. An overview of qualitative and quantitative analyses of all exposure–outcome associations is shown in table 1. Figures 2 and 3 depict quantitative analyses, while table 2 contains an overview of any exposure–outcome associations that could not be statistically pooled.

Direct exposure

The exposure–outcome associations for direct exposures were quantitatively analysed for: number of army deployments (OR (95% CI): 1.15 (1.14 to 1.16), $I^2=0\%$, $n=333\,024$, figure 2), combat exposure (OR (95% CI): 1.89 (1.46 to 2.45), $I^2=89\%$, $n=28\,304$, figure 2) and army deployment (OR (95% CI): 1.79 (1.45 to 2.21), $I^2=0\%$, $n=11\,023$, figure 3). The PAFs for these exposures were 7%, 14% and 34%, respectively. Evidence for these exposure–outcome associations was moderate, very low and low quality, respectively. In some cases, the evidence was downgraded due to high risk of bias and inconsistency. There was some evidence for publication bias, although it was only possible to assess that for the ‘combat exposure’ variable (online supplemental file 6). Subgroup analyses based on risk of bias (online supplemental files 7–9), study design (online supplemental files 10–12) and PTSD ascertainment (online supplemental files 13–15) showed no statistically significant differences between effects for those subgroups.

In our qualitative analyses of exposures that could not be statistically pooled, we found exposure–outcome associations for exposures related to undergoing a traumatic event, cumulative exposure and the severity of exposure (table 2). With regard to undergoing a traumatic event, the effect sizes ranged from OR (95% CI): 0.86 (0.32 to 2.28) (physical contacts with thieves)³⁴ to OR (95% CI): 5.65 (3.27 to 9.74) (workers fleeing from a tsunami).⁴² Cumulative exposure was, for example, expressed in length of deployment³⁷ (OR (95% CI): 0.97 (0.92 to 1.03)) and high frequency of violence (compared with no violence)⁵⁵ (OR (95% CI): 6.5 (1.6 to 25.6)). The effect sizes for exposure severity ranged from OR (95% CI): 1.01 (0.67 to 1.35) (severity of battles)⁴⁵ to OR (95% CI): 6.5 (1.6 to 26.0) (severe compared with no violence).⁵⁵

Witnessing a trauma

With regard to the DSM-5 criterion ‘witnessing a trauma’, there was insufficient homogeneous data to pool studies statistically (table 2). In five studies (with $n=4876$

Table 1 Overview of the evidence from both qualitative and quantitative analyses, with exposures categorised according to DSM-5 criteria

DSM-5 criterion	Exposure	N	N	Limit*	Inconst	Indirect†	Imprec‡	Pub bias§	OR (95% CI)**	Grad††	GRADE	PAF	Reference
Direct exposure	No of army deployments‡‡	3	333 024	No	0%	No	No	N/A	1.15 (1.14 to 1.16)	No	Moderate	7%	Figure 2
	Combat exposure	11	28 304	Yes	89%	No	No	Yes	1.89 (1.46 to 2.45)	No	Very low	14%	Figure 2
	Army deployment§§	4	11 023	Yes	0%	No	No	N/A	1.79 (1.45 to 2.21)	No	Low	34%	Figure 3
Indirect exposure	Undergoing a traumatic event	13	1 703 107	-	-	-	-	-	Min: 0.86 (0.32 to 2.28) Max: 5.65 (3.27 to 9.74)	-	-	-	Table 2
	Cumulative exposure	8	1 749 762	-	-	-	-	-	Min: 0.97 (0.92 to 1.03) Max: 6.5 (1.6 to 25.6)	-	-	-	Table 2
Witnessing trauma	Exposure severity	3	2 558	-	-	-	-	-	Min: 1.01 (0.67 to 1.35) Max: 6.5 (1.6 to 26.0)	-	-	-	Table 2
	-	5	4 876	-	-	-	-	-	Min: 1.01 (0.63 to 1.64) Max: 9.3 (6.1 to 14.2)	-	-	-	Table 2
Colleague exposed¶¶	-	1	980	-	-	-	-	-	0.55 (0.12 to 2.47)	-	-	-	Table 2
	Confrontation with death	7	75 902	No	46%	No	No	N/A	1.63 (1.41 to 1.90)	No	Moderate	15%	Figure 3
Other exposures	-	4	14 085	-	-	-	-	-	Min: 1.03 (1.00 to 1.06) Max: 4.0 (2.5 to 6.6)	-	-	-	Table 2
	Stress	4	1 390 641	-	-	-	-	-	Min: 1.01 (0.98 to 1.04) Max: 3.52 (2.94 to 4.21)	-	-	-	Table 2
	Time since event	3	1 358 468	-	-	-	-	-	Min: 0.47 (0.32 to 0.70) Max: 1.89 (0.99 to 3.60)	-	-	-	Table 2
Other	-	3	69 176	-	-	-	-	-	Min: 1.08 (0.97 to 1.20) Max: 5.72 (3.37 to 9.71)	-	-	-	Table 2

For exposures for which quantitative analyses could be performed (figures 2 and 3), quality of the evidence for the relationship between work-related exposures and PTSD according to the GRADE framework is shown. Other exposures are described qualitatively (table 2).

*Limitation: downgraded if the majority of studies score lower than 60% on the risk of bias scale.

†Inconsistency: downgrade if $I^2 \geq 50\%$.

‡Indirectness: downgrade if indirectness is present.

§Imprecision: downgrade if the 95% CI is <1 and >2 .

¶Publication bias: downgraded if publication bias is present (based on the funnel plots).

**Effect size: upgrade if the lower limit of the 95% CI is >2.0 .

††Gradient: upgraded if there is a dose-response gradient available.

‡‡Depicting the effect of being deployed more than once, as compared with not being deployed.

§§Depicting the effect of being deployed, as compared with not being deployed.

¶¶For this study on occupational exposures, the DSM-5 criterion 'relative/friend' was adapted to 'colleague or coworker'.

DSM-5, Diagnostic and Statistical Manual of Mental Disorders, fifth edition; GRADE, Grades of Recommendations, Assessment, Development and Evaluation; NA, not available; PAF, population attributable fractions; PTSD, post-traumatic stress disorder.

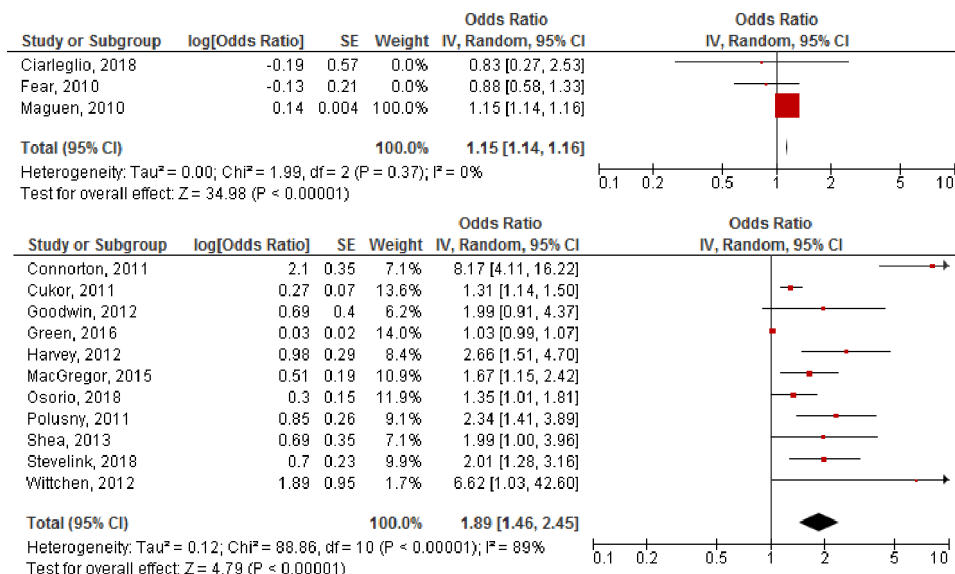


Figure 2 Study findings (ie, effect sizes) for articles reporting on the association of number of army deployments (depicting the effect of being deployed more than once, as compared with being deployed once; upper panel) and combat exposure (lower panel) with PTSD. Individual study as well as pooled effects are presented. IV, inverse variance; PTSD, post-traumatic stress disorder.

participants), effect sizes ranged from OR (95% CI): 1.01 (0.63 to 1.64) ('perceiving a life threat')⁵⁶ to OR (95% CI): 9.3 (6.1 to 14.2) ('being present during an attack').³⁸

A colleague or coworker was exposed to a trauma

Only one study (n=980) reported on effect sizes regarding 'colleague or coworker exposed to a trauma'. This study, among public transport workers, found that 'hearing that a close colleague had suffered a person under train experience' was not significantly associated with PTSD (OR (95% CI): 0.55 (0.12 to 2.47))⁴⁶

Indirect exposure to aversive details

Regarding indirect exposure to adverse events, we statistically pooled the effect sizes from seven studies (n=75 902

participants) with moderate-quality evidence for an association between confrontation with death and PTSD (figure 3; OR (95% CI): 1.63 (1.41 to 1.90)). Subgroup analyses regarding risk of bias (online supplemental file 16), study design (online supplemental file 17) and PTSD ascertainment (online supplemental file 18) showed no statistically significant differences between any of those subgroups.

Additional evidence from four studies (n=14 085 participants), which could not be statistically pooled, showed effect sizes ranging from OR (95% CI): 1.03 (1.00 to 1.06) (being exposed to the aftermath of a battle)³⁷ to OR (95% CI): 4.0 (2.5 to 6.6) (being present during the morning of the 9/11 attacks).²⁷

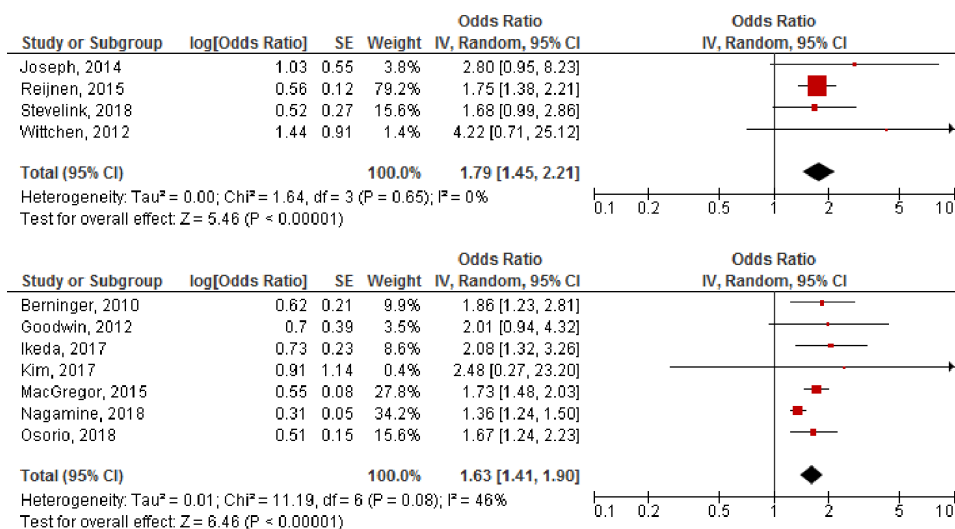


Figure 3 Study findings (ie, effect sizes) for articles reporting on the association of deployments status (depicting the effect of being deployed, as compared with not being deployed; upper panel) and confrontation with death (lower panel) with PTSD. Individual study as well as pooled effects are presented. IV, Inverse variance; PTSD, post-traumatic stress disorder.

Table 2 Overview of all exposure–outcome effect sizes from qualitative analyses, with exposures categorised according to DSM-5 criteria

DSM-5 criterion	Exposure category	Exposure	Effect size (OR (95% CI))
Direct exposure	Undergoing an event	Work-related threats ²⁰	1.10 (1.04 to 1.15)
		Work-related violence ²⁰	1.02 (0.98 to 1.06)
		Previous disaster experience ²³	1.4 (1.2 to 1.6)
		One injury sustained during the 9/11 attacks ²⁹	1.1 (0.6 to 2.0)
		Two or more injuries sustained during the 9/11 attacks ²⁹	1.4 (0.6 to 3.4)
		Participation in abusive violence ³³	3.32 (1.81 to 6.08)
		Robberies during working life ³⁴	1.18 (0.97 to 1.44)
		Physical contacts with robbers ³⁴	0.86 (0.32 to 2.28)
		Scuffle (taking part or being present) ³⁴	1.92 (0.63 to 5.79)
		Being injured during the robbery ³⁴	1.28 (0.31 to 5.21)
		Discharged weapon on deployment ³⁶	1.48 (0.61 to 3.60)
		Experience of life-threatening danger ⁴²	4.32 (2.89 to 6.48)
		Major property loss ⁴²	3.45 (2.28 to 5.23)
		Escape from tsunami ⁴²	5.65 (3.27 to 9.74)
		Life threatening war ⁴⁵	1.91 (1.07 to 3.24)
		Conflict with passengers ⁴⁶	3.21 (1.14 to 9.03)
		Felt in great danger of being killed ⁴⁸	3.44 (2.50 to 4.72)
		Exposure to blast ⁵⁰	4.72 (2.9 to 7.7)
		Encountering explosive devices ⁵⁴	1.26 (0.95 to 1.66)
		Cumulative exposure	
Length of deployment ³⁷	0.97 (0.92 to 1.03)		
≥5 critical cases per call for traumatic surgeons ⁴³	7 (1.1 to 8)		
≥7 call duties a month for traumatic surgeons ⁴³	3.8 (0.9 to 7.2)		
≥15 operative cases per month ⁴³	2.8 (0.4 to 3.2)		
Cumulative years deployed in navy ⁴⁷	2.04 (1.93 to 2.15)		
Cumulative years deployed in army ⁴⁷	1.74 (1.71 to 1.76)		
No of combat exposures ⁴⁸	1.62 (1.46 to 1.79)		
Two combat exposure deployment ⁴⁸	1.37 (1.17 to 1.61)		
Three combat exposure deployment ⁴⁸	1.30 (0.94 to 1.82)		
Two deployments ⁴⁸	1.00 (1.00 to 1.01)		
Three deployments ⁴⁸	1.00 (0.99 to 1.01)		
One exposure (compared with no exposure) ⁵⁰	4.67 (3.1 to 7.1)		
Two or more deployments (compared with no exposure) ⁵⁰	6.15 (4.4 to 8.7)		
Deployment length 1–3 months ⁵³	1.53 (1.37 to 1.70)		
Deployment length ≥3 months ⁵³	2.64 (2.33 to 2.99)		
Low frequency of violence (compared with no violence) ⁵⁵	4.0 (1.0 to 16.3)		
Medium frequency of violence (compared with no violence) ⁵⁵	5.9 (1.4 to 24.2)		
High frequency of violence (compared with no violence) ⁵⁵	6.5 (1.6 to 25.6)		
Exposure severity			
		Severity of battles ⁴⁵	1.01 (0.67 to 1.35)
		Max. mild violence (compared with no violence) ⁵⁵	3.8 (0.3 to 46.2)
		Max. threats of violence (compared with no violence) ⁵⁵	5.4 (1.2 to 24.2)
		Max. moderate violence (compared with no violence) ⁵⁵	2.6 (0.6 to 10.8)

Continued

Table 2 Continued

DSM-5 criterion	Exposure category	Exposure	Effect size (OR (95% CI))
Witnessing the trauma		Max. severe violence (compared with no violence) ⁵⁵	6.5 (1.6 to 26.0)
		Perceived life threat ⁵⁶	1.01 (0.63 to 1.64)
		Observation of abusive violence ³³	8.36 (4.56 to 15.35)
		Presence during attack ³⁸	9.3 (6.1 to 14.2)
		Witnessing of plant explosions ⁴²	2.09 (1.43 to 3.06)
		Person under train experience ⁴⁶	1.54 (0.52 to 4.55)
		One person under train experiences ⁴⁶	1.77 (0.31 to 4.47)
		Two or more person under train experiences ⁴⁶	2.36 (0.57 to 9.70)
		Sudden train stop ⁴⁶	3.66 (0.82 to 16.4)
		Near train accident ⁴⁶	8.81 (1.96 to 39.3)
Colleague exposed		Damage to train ⁴⁶	1.71 (0.48 to 6.14)
Indirect exposure to aversive details		Person under train experience of colleague ⁴⁶	0.55 (0.12 to 2.47)
		Aftermath of battle ³⁷	1.03 (1.00 to 1.06)
		Morning of 9/11 (compared with >3 days) ²⁷	4.0 (2.5 to 6.6)
		Afternoon of 9/11 (compared with >3 days) ²⁷	2.1 (1.3 to 3.3)
		Day 2 (compared with >3 days) ²⁷	1.4 (0.9 to 2.4)
		Morning of 9/11 (compared with >3 days) ²³	2.0 (1.3 to 2.9)
		Afternoon of 9/11 (compared with >3 days) ²³	1.1 (0.8 to 1.5)
Other exposures	Stress	Exposure to aftermath of battle ⁵⁶	1.81 (1.08 to 3.06)
		High deployment stress ²¹	3.52 (2.94 to 4.21)
		Deployment concerns summary score ²⁸	1.01 (0.98 to 1.04)
		Worried by other issues related to robbery ³⁴	2.64 (0.95 to 7.36)
		Unit cumulative high deployment stress rate (marine) ⁴⁷	1.04 (1.03 to 1.05)
		Unit cumulative high deployment stress rate (army) ⁴⁷	1.05 (1.04 to 1.06)
	Time since event	Months since most recent deployment ²⁸	1.00 (0.98 to 1.02)
		Time since return from deployment (up to 2 years) ³²	1.18 (0.75 to 1.86)
		Time since return from deployment (up to 3 years) ³²	1.80 (1.05 to 3.10)
		Time since return from deployment (up to 4 years) ³²	1.88 (0.98 to 3.62)
		Time since return from deployment (up to 5 years) ³²	1.53 (0.92 to 2.55)
		Time since return from deployment (up to 6.5 years) ³²	1.89 (0.99 to 3.60)
		Dwell to deployment ratio (1:1 vs <1:1) ⁴⁸	0.83 (0.60 to 1.13)
		Dwell to deployment ratio (2:1 vs <1:1) ⁴⁸	0.47 (0.32 to 0.70)
	Other	Supervising responsibilities ²³	2.2 (1.7 to 2.9)
Discrimination/slurs ⁴²		5.72 (3.37 to 9.71)	
Duties with radiation exposure risk ⁵³		1.08 (0.97 to 1.20)	

OR with 95% CI are shown.

DSM-5, Diagnostic and Statistical Manual of Mental Disorders, fifth edition; WTC, World Trade Center .

Other exposures

We found additional evidence that could not be categorised into any of the DSM-5 criteria. An increased risk of PTSD was associated with experiencing stress, with evidence ranging from OR (95% CI): 1.01 (0.98 to 1.04) (deployment concerns)²⁸ to OR (95% CI): 3.52 (2.94 to 4.21) (high deployment stress).²¹ Also, the time

that has passed since a given traumatic event seems to be associated with PTSD. This factor can either reduce the PTSD risk (OR (95% CI): 0.47 (0.32 to 0.70) with a longer dwell time between deployments)⁴⁸ or increase it (OR (95% CI): 1.89 (0.99 to 3.60) if the period since the return from deployment exceeds 6.5 years).³² Other exposures included experiencing discrimination at

work (OR (95% CI): 5.72 (3.37 to 9.71))⁴² and having to perform duties that involved a risk of radiation exposure (OR (95% CI): 1.08 (0.97 to 1.20)).⁵³

DISCUSSION

In this systematic review with meta-analysis and evidence grading, we found various associations, although based on moderate-quality evidence at best, showing that several work-related exposures are associated with PTSD development. This includes exposures such as the number of army deployments, combat exposure, army deployment and confrontation with death. The corresponding effect sizes ranged from 1.15 (1.14 to 1.16) to 1.89 (1.46 to 2.45) and PAFs varied from 7% (for the number of army deployments) to 34% (for army deployment). The latter values indicate the proportion of PTSD cases that could potentially be avoided in a working population, if the exposure in question were to be totally eliminated. The data suggest that there could be an only moderate relationship between PTSD and work situations. However, they could also indicate that PTSD cannot be attributed to a single work-related exposure and that it is multifactorial in nature and/or is mediated by other factors. This could, perhaps, also account for the relatively low ORs found for some of the effects.

Only a limited data, which could not be statistically pooled, was available concerning exposures that corresponded to the DSM-5 criteria 'witnessing a trauma' and 'hearing that a colleague/coworker was exposed to a trauma'. These exposures include 'perceiving a life threat', 'being present during an attack' and 'hearing that a close colleague had suffered a person under train experience'. The additional exposures that could not be categorised according to DSM-5 criteria include 'military deployment', 'deployment stress' and 'time since return from deployment'. In future, it may be worth considering exposures of this kind when diagnosing work-related PTSD.

The details uncovered by this review are key to a better understanding of work-related causes of PTSD, to the selection or development of preventive interventions, and to the identification of thresholds for occupational health guidelines. This review has updated earlier work^{7,9} and we are the first to quantify the association between work-related exposures and PTSD. This update identifies occupational groups and exposures that do not feature in previous reviews, such as public transport workers⁴⁶ and bank workers (being exposed to robberies).³⁴

Although the prevention of occupational diseases, including PTSD, is preferable, not all risks can be fully eliminated as witnessing traumatic events, disasters and war situations are likely to remain present in our working situations. In the working environment it is also important to attenuate the impact of exposures on workers or to treat them when having developed work-related PTSD. In the current review, we also identified work-related factors that can reduce the risk of PTSD, which can be helpful to

attenuate the impact of stressful exposures. For instance, among highly exposed occupational groups, a high level of preparedness (OR (95% CI): 0.6 (0.4 to 0.9)),⁶² unit support (OR (95% CI): 0.5 (0.3 to 0.8)),⁶² postdeployment support (OR (95% CI): 0.3 (0.2 to 0.4))⁶² and social support (OR (95% CI): 0.96 (0.93 to 0.98))³⁷ were all found to be associated with a reduced risk of PTSD. These elements can be used in the development of interventions, especially for those in occupations that involve high PTSD risks.

Methodological strengths and limitations

The strengths of this review are the systematic methods used plus a protocol that was registered a priori, the systematic review with meta-analysis and the assessment of evidential quality using GRADE.¹⁸ The findings appear to be quite robust, since subgroup analyses based on risk of bias, study design and PTSD ascertainment produced results that did not differ between any of those subgroups. Moreover, the PAFs estimated in our study provide insight into the extent to which the identified exposures were occupationally related to PTSD.

We deviated from our a priori registered protocol¹³ in that we were unable to compare different PTSD diagnoses (acute vs delayed). In our meta-analysis, we used effect sizes from the article with the shortest follow-up duration (with a latency time of at least 4 weeks). There were, however, also data available from few studies measuring both the short-term and long-term effects of exposure and their association with PTSD. For example, 'being present during a terrorist attack' was strongly associated with PTSD in the acute phase (after 10 months; OR (95% CI): 9.3 (6.1 to 14.2)), but this association was even stronger in the long term (after 34 months; OR (95% CI): 10.0 (5.4 to 18.6)).³⁸ Regarding 'being exposed to combat', the opposite was true. Stronger effects were seen in short term (OR (95% CI): 2.91 (1.34 to 6.31)) than long term (OR (95% CI): 2.42 (1.04 to 5.62)).³⁹ This is in line with another review indicating that, following exposure, the risk of PTSD attenuates over time.⁷

Another potential source of heterogeneity stems from the method used to ascertain PTSD. In 25 articles, PTSD was assessed by clinical diagnosis while 17 articles assessed probable PTSD/PTSD symptoms, based on self-reports using predefined (eg, DSM-5) criteria. We found that the average prevalence was slightly higher for diagnosed PTSD (7.3%) than for probable PTSD (6.4%). This is in line with a study of disaster workers, following the 9/11 attacks, in which 2%–9% had probable self-reported PTSD, respectively.³¹ However, 6%–15% of these workers were diagnosed with PTSD. Nevertheless, our pooled effect sizes were robust across different methods for ascertaining PTSD. While ascertaining PTSD by clinical diagnosis may be more valid, this source of heterogeneity is unlikely to have substantially affected the findings presented. We have only assessed incidence of PTSD. Accordingly, this review does not address the persistence or growth of PTSD. Future studies should, therefore, focus on different types of PTSD diagnoses. They should also assess



the work-relatedness of PTSD persistence and growth, as an aid to the development of occupational health guidelines.

One limitation of our study is that the majority of the studies in this review were based on participants from armed forces (N=21) and first responders (N=5). There was limited information on other occupations, such as public transport workers, bank employees and healthcare workers. Furthermore, most studies of the armed forces and of first responders tend to be male dominated and from Western countries. Future research should address these issues, by assessing previously unexplored occupational sectors and groups, as well as data from other countries. In this review, we only included longitudinal studies in which the exposure would precede the outcome, as a result of which a better inference of causality can be provided than with cross-sectional studies only. Moreover, we focused in our review on articles published from 2005 onwards. This cut-off was based on changes in people's exposure to work-related traumatic events and changes to the definition of PTSD over time.²

While our use of the GRADE framework provides an adequate way to assess quality of the evidence, it does not necessarily provide insights into causation of the association of work-related exposures and PTSD, for which other approaches such as the Bradford Hill criteria⁶³ could be used. It has been argued that the majority of the Bradford Hill criteria are to some extent incorporated in GRADE, such as the strength and consistency of the association.⁶⁴ Other criteria, such as that of the biological plausibility, are not well covered nor are they in the current review evidence regarding work-related PTSD. Future studies should, therefore, aim at providing more insights into this, to further build the evidence base around work-related PTSD and the biology of risk for PTSD.⁶⁵ Although methodological quality of the included studies was of an acceptable level (62%, on average), the quality of the evidence was rated moderate at best. More than half of the articles showed a risk of bias with regard to participation (ie, selection bias), attrition (with <80% of the participants being retained during the follow-up period) and misclassification due to a limited assessment of the prognostic factors (ie, exposure) and the outcome of interest. As mentioned above, the ascertainment of PTSD is unlikely to have caused a substantial bias in our findings. However, exposures were often measured by means of self-reports, which may well have biased our findings. In addition, the quality of the evidence was downgraded due to inconsistency for some of the exposures. Our assessment of publication bias was limited to just one of the pooled exposures. It appeared, however, that none of the studies had published or registered their protocol, which could have caused publication bias.

CONCLUSION

In this systematic review with meta-analysis of 33 studies (with n=5719236 participants), based on moderate quality evidence at best, we identified a number of work-related exposures (mainly involving individuals in the armed forces and in first responder occupations) that increase the risk of PTSD (by 15%–89%). These exposures include 'number

of army deployments', 'combat exposure', 'army deployment' and 'confrontation with death', for which we found a moderate contribution to the development of PTSD. We identified additional exposures in other occupations, such as bank workers, public transport workers and medics. These included 'life threats', 'being present during an attack' and 'hearing about a colleague's trauma'. Although exposure assessment, PTSD ascertainment and inconsistency may have biased our findings, the results of this review are quite robust and are of importance for the development of preventive interventions and occupational health guidelines.

Acknowledgements We would like to thank Teus Brand, Bas Sorgdrager and Gerda de Groene for their critical appraisal and the relevant feedback provided. We would like to thank Joost Daams for helping us with the search for literature.

Contributors Both authors (PC and HFvdM) designed the study and reviewed the manuscript for important intellectual content. Both authors identified relevant articles and conducted data extraction and analyses together. PC drafted the first version of the manuscript. HFvdM is the study guarantor.

Funding The study has been funded by the Dutch Ministry of Social Affairs and Employment (grant no. 22968).

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as online supplemental information.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iDs

Pieter Coenen <http://orcid.org/0000-0002-4034-7063>

Henk F van der Molen <http://orcid.org/0000-0002-0719-2020>

REFERENCES

- 1 American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*. 3rd ed. Washington DC, USA, 1980.
- 2 American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*. 5th ed. Washington DC, USA, 2013.
- 3 Sareen J. Posttraumatic stress disorder in adults: impact, comorbidity, risk factors, and treatment. *Can J Psychiatry* 2014;59:460–7.
- 4 Knowles KA, Sripada RK, Defever M, et al. Comorbid mood and anxiety disorders and severity of posttraumatic stress disorder symptoms in treatment-seeking veterans. *Psychol Trauma* 2019;11:451–8.
- 5 Debell F, Fear NT, Head M, et al. A systematic review of the comorbidity between PTSD and alcohol misuse. *Soc Psychiatry Psychiatr Epidemiol* 2014;49:1401–25.
- 6 Pompili M, Sher L, Serafini G, et al. Posttraumatic stress disorder and suicide risk among veterans: a literature review. *J Nerv Ment Dis* 2013;201:802–12.
- 7 Skogstad M, Skorstad M, Lie A, et al. Work-Related post-traumatic stress disorder. *Occup Med* 2013;63:175–82.

- 8 Utzon-Frank N, Breinegaard N, Bertelsen M, *et al.* Occurrence of delayed-onset post-traumatic stress disorder: a systematic review and meta-analysis of prospective studies. *Scand J Work Environ Health* 2014;40:215–29.
- 9 Lee W, Lee Y-R, Yoon J-H, *et al.* Occupational post-traumatic stress disorder: an updated systematic review. *BMC Public Health* 2020;20:768.
- 10 van der Beek AJ, Dennerlein JT, Huysmans MA, *et al.* A research framework for the development and implementation of interventions preventing work-related musculoskeletal disorders. *Scand J Work Environ Health* 2017;43:526–39.
- 11 van der Molen HF, Foresti C, Daams JG, *et al.* Work-related risk factors for specific shoulder disorders: a systematic review and meta-analysis. *Occup Environ Med* 2017;74:745–55.
- 12 Kuijer PPFM, Verbeek JH, Seidler A, *et al.* Work-relatedness of lumbosacral radiculopathy syndrome: review and dose-response meta-analysis. *Neurology* 2018;91:558–64.
- 13 Coenen P, Brand T, Sorgdrager B, *et al.* What work-related risk factors are associated with post-traumatic stress disorder? PROSPERO 2020;CRD4202155434.
- 14 Moher D, Liberati A, Tetzlaff J, *et al.* Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009;339:b2535.
- 15 Hayden JA, van der Windt DA, Cartwright JL, *et al.* Assessing bias in studies of prognostic factors. *Ann Intern Med* 2013;158:280–6.
- 16 Cochrane Collaboration. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]. Available: www.cochrane-handbook.org.2011
- 17 Poole C. A history of the population attributable fraction and related measures. *Ann Epidemiol* 2015;25:147–54.
- 18 Hugueta A, Hayden JA, Stinson J, *et al.* Judging the quality of evidence in reviews of prognostic factor research: adapting the grade framework. *Syst Rev* 2013;2:71.
- 19 Foroutan F, Guyatt G, Zuk V, *et al.* Grade guidelines 28: use of grade for the assessment of evidence about prognostic factors: rating certainty in identification of groups of patients with different absolute risks. *J Clin Epidemiol* 2020;121:62–70.
- 20 Andersen LP, Høgh A, Elklit A, *et al.* Work-related threats and violence and post-traumatic symptoms in four high-risk occupations: short- and long-term symptoms. *Int Arch Occup Environ Health* 2019;92:195–208.
- 21 Anderson L, Campbell-Sills L, Ursano RJ, *et al.* Prospective associations of perceived unit cohesion with postdeployment mental health outcomes. *Depress Anxiety* 2019;36:511–21.
- 22 Armed Forces Health Surveillance Center. Associations between repeated deployments to Iraq (OIF/OND) and Afghanistan (OEF) and post-deployment illnesses and injuries, active component, U.S. Armed Forces, 2003–2010. Part II. Mental disorders, by gender, age group, military occupation, and "dwell times" prior to repeat (second through fifth) deployments. *MSMR* 2011;18:2–11.
- 23 Berninger A, Webber MP, Niles JK, *et al.* Longitudinal study of probable post-traumatic stress disorder in firefighters exposed to the world Trade center disaster. *Am J Ind Med* 2010;53:1177–85.
- 24 Brownlow JA, Zitnik GA, McLean CP, *et al.* The influence of deployment stress and life stress on post-traumatic stress disorder (PTSD) diagnosis among military personnel. *J Psychiatr Res* 2018;103:26–32.
- 25 Brundage JF, Taubman SB, Hunt DJ, *et al.* Whither the "signature wounds of the war" after the war: estimates of incidence rates and proportions of TBI and PTSD diagnoses attributable to background risk, enhanced ascertainment, and active war zone service, active component, U.S. Armed Forces, 2003–2014. *MSMR* 2015;22:2–11.
- 26 Cameron KL, Sturdivant RX, Baker SP. Trends in the incidence of physician-diagnosed posttraumatic stress disorder among active-duty U.S. military personnel between 1999 and 2008. *Mil Med Res* 2019;6:8.
- 27 Chiu S, Niles JK, Webber MP, *et al.* Evaluating risk factors and possible mediation effects in posttraumatic depression and posttraumatic stress disorder comorbidity. *Public Health Rep* 2011;126:201–9.
- 28 Ciarleglio MM, Aslan M, Proctor SP, *et al.* Associations of stress exposures and social support with long-term mental health outcomes among U.S. Iraq war veterans. *Behav Ther* 2018;49:653–67.
- 29 Cone JE, Li J, Kornblith E, *et al.* Chronic probable PTSD in police responders in the world Trade center health registry ten to eleven years after 9/11. *Am J Ind Med* 2015;58:483–93.
- 30 Connorton E, Perry MJ, Hemenway D, *et al.* Occupational trauma and mental illness—combat, peacekeeping, or relief work and the national co-morbidity survey replication. *J Occup Environ Med* 2011;53:1360–3.
- 31 Cukor J, Wyka K, Mello B, *et al.* The longitudinal course of PTSD among disaster workers deployed to the World Trade center following the attacks of September 11th. *J Trauma Stress* 2011;24:506–14.
- 32 Fear NT, Jones M, Murphy D, *et al.* What are the consequences of deployment to Iraq and Afghanistan on the mental health of the UK armed forces? a cohort study. *Lancet* 2010;375:1783–97.
- 33 Ferrajão PC, Oliveira RA. The effects of combat exposure, abusive violence, and sense of coherence on PTSD and depression in Portuguese colonial war veterans. *Psychol Trauma* 2016;8:1–8.
- 34 Fichera GP, Fattori A, Neri L, *et al.* Post-Traumatic stress disorder among bank employee victims of robbery. *Occup Med* 2015;65:283–9.
- 35 Fink DS, Cohen GH, Sampson LA, *et al.* Incidence of and risk for post-traumatic stress disorder and depression in a representative sample of US reserve and national guard. *Ann Epidemiol* 2016;26:189–97.
- 36 Goodwin L, Jones M, Rona RJ, *et al.* Prevalence of delayed-onset posttraumatic stress disorder in military personnel: is there evidence for this disorder?: results of a prospective UK cohort study. *J Nerv Ment Dis* 2012;200:429–37.
- 37 Green JD, Bovin MJ, Erb SE, *et al.* The effect of enemy combat tactics on PTSD prevalence rates: a comparison of operation Iraqi freedom deployment phases in a sample of male and female veterans. *Psychol Trauma* 2016;8:634–40.
- 38 Hansen MB, Birkeland MS, Nissen A, *et al.* Prevalence and course of symptom-defined PTSD in individuals directly or indirectly exposed to terror: a longitudinal study. *Psychiatry* 2017;80:171–83.
- 39 Harvey SB, Hatch SL, Jones M, *et al.* The long-term consequences of military deployment: a 5-year cohort study of United Kingdom reservists deployed to Iraq in 2003. *Am J Epidemiol* 2012;176:1177–84.
- 40 Horesh D, Solomon Z, Zerach G, *et al.* Delayed-Onset PTSD among war veterans: the role of life events throughout the life cycle. *Soc Psychiatr Psychiatr Epidemiol* 2011;46:863–70.
- 41 Hourani L, Bender RH, Weimer B, *et al.* Longitudinal study of resilience and mental health in Marines leaving military service. *J Affect Disord* 2012;139:154–65.
- 42 Ikeda A, Tanigawa T, Charvat H, *et al.* Longitudinal effects of disaster-related experiences on mental health among Fukushima nuclear plant workers: the Fukushima news project study. *Psychol Med* 2017;47:1936–46.
- 43 Joseph B, Pandit V, Hadeed G, *et al.* Unveiling posttraumatic stress disorder in trauma surgeons: a national survey. *J Trauma Acute Care Surg* 2014;77:148–54.
- 44 Karstoft K-I, Armour C, Elklit A, *et al.* Long-Term trajectories of posttraumatic stress disorder in veterans: the role of social resources. *J Clin Psychiatry* 2013;74:e1163–8.
- 45 Karstoft K-I, Armour C, Elklit A, *et al.* The role of locus of control and coping style in predicting longitudinal PTSD-trajectories after combat exposure. *J Anxiety Disord* 2015;32:89–94.
- 46 Kim S-E, Kim H-R, Park J-I, *et al.* The association between psychiatric disorders and work-related problems among subway drivers in Korea. *Ann Occup Environ Med* 2014;26:39.
- 47 Levin-Rector A, Hourani LL, Van Dorn RA, *et al.* Predictors of posttraumatic stress disorder, anxiety disorders, depressive disorders, and any mental health condition among U.S. soldiers and Marines, 2001–2011. *J Trauma Stress* 2018;31:568–78.
- 48 MacGregor AJ, Dougherty AL, Mayo JA, *et al.* Post-Traumatic stress disorder among navy health care personnel following combat deployment. *Mil Med* 2015;180:882.
- 49 MacGregor AJ, Han PP, Dougherty AL, *et al.* Effect of dwell time on the mental health of US military personnel with multiple combat tours. *Am J Public Health* 2012;102 Suppl 1:S55–9.
- 50 Maguen S, Madden E, Lau KM, *et al.* The impact of head injury mechanism on mental health symptoms in veterans: do number and type of exposures matter? *J Trauma Stress* 2012;25:3–9.
- 51 Maguen S, Ren L, Bosch JO, *et al.* Gender differences in mental health diagnoses among Iraq and Afghanistan Veterans enrolled in Veterans Affairs health care. *Am J Public Health* 2010;100:2450–6.
- 52 Martindale SL, Rowland JA, Shura RD, *et al.* Longitudinal changes in neuroimaging and neuropsychiatric status of post-deployment veterans: a CenC pilot study. *Brain Inj* 2018;32:1208–16.
- 53 Nagamine M, Yamamoto T, Shigemura J, *et al.* The psychological impact of the great East Japan earthquake on Japan ground self-defense force personnel: a three-wave, one-year longitudinal study. *Psychiatry* 2018;81:1–9.
- 54 Osório C, Jones N, Jones E, *et al.* Combat experiences and their relationship to post-traumatic stress disorder symptom clusters in UK military personnel deployed to Afghanistan. *Behav Med* 2018;44:131–40.



- 55 Pihl-Thingvad J, Andersen LL, Brandt LPA, *et al.* Are frequency and severity of workplace violence etiologic factors of posttraumatic stress disorder? A 1-year prospective study of 1,763 social educators. *J Occup Health Psychol* 2019;24:543–55.
- 56 Polusny MA, Erbes CR, Murdoch M, *et al.* Prospective risk factors for new-onset post-traumatic stress disorder in national guard soldiers deployed to Iraq. *Psychol Med* 2011;41:687–98.
- 57 Reijnen A, Rademaker AR, Vermetten E, *et al.* Prevalence of mental health symptoms in Dutch military personnel returning from deployment to Afghanistan: a 2-year longitudinal analysis. *Eur Psychiatry* 2015;30:341–6.
- 58 Tracie Shea M, Reddy MK, Tyrka AR, *et al.* Risk factors for post-deployment posttraumatic stress disorder in national guard/reserve service members. *Psychiatry Res* 2013;210:1042–8.
- 59 Soo J, Webber MP, Gustave J, *et al.* Trends in probable PTSD in firefighters exposed to the world Trade center disaster, 2001–2010. *Disaster Med Public Health Prep* 2011;5:S197–203.
- 60 Stevelink SAM, Jones M, Hull L, *et al.* Mental health outcomes at the end of the British involvement in the Iraq and Afghanistan conflicts: a cohort study. *Br J Psychiatry* 2018;213:690–7.
- 61 Wittchen H-U, Schönfeld S, Kirschbaum C, *et al.* Traumatic experiences and posttraumatic stress disorder in soldiers following deployment abroad: how big is the hidden problem? *Dtsch Arztebl Int* 2012;109:559–68.
- 62 Goldmann E, Calabrese JR, Prescott MR, *et al.* Potentially modifiable pre-, peri-, and postdeployment characteristics associated with deployment-related posttraumatic stress disorder among Ohio army national guard soldiers. *Ann Epidemiol* 2012;22:71–8.
- 63 HILL AB, Bradford Hill A. The environment and disease: association or causation? *Proc R Soc Med* 1965;58:295–300.
- 64 Schünemann H, Hill S, Guyatt G, *et al.* The grade approach and Bradford Hill's criteria for causation. *J Epidemiol Community Health* 2011;65:392–5.
- 65 Nievergelt CM, Maihofer AX, Klengel T, *et al.* International meta-analysis of PTSD genome-wide association studies identifies sex- and ancestry-specific genetic risk loci. *Nat Commun* 2019;10:4558.