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Post-traumatic stress disorder associated with natural and human-made disasters in the World Mental Health Surveys

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Declaration of Interest
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Abstract

Background—Research on post-traumatic stress disorder (PTSD) following natural and human-made disasters has been undertaken for more than three decades. Although PTSD prevalence estimates vary widely, most are in the 20–40% range in disaster-focused studies but considerably lower (3–5%) in the few general population epidemiological surveys that evaluated disaster-related PTSD as part of a broader clinical assessment. The World Mental Health (WMH) Surveys provide an opportunity to examine disaster-related PTSD in representative general population surveys across a much wider range of sites than in previous studies.

Method—Although disaster-related PTSD was evaluated in 18 WMH surveys, only six in high-income countries had enough respondents for a risk factor analysis. Predictors considered were socio-demographics, disaster characteristics, and pre-disaster vulnerability factors (childhood family adversities, prior traumatic experiences, and prior mental disorders).

Results—Disaster-related PTSD prevalence was 0.0–3.8% among adult (ages 18+) WMH respondents and was significantly related to high education, serious injury or death of someone close, forced displacement from home, and pre-existing vulnerabilities (prior childhood family adversities, other traumas, and mental disorders). Of PTSD cases 44.5% were among the 5% of respondents classified by the model as having highest PTSD risk.

Conclusion—Disaster-related PTSD is uncommon in high-income WMH countries. Risk factors are consistent with prior research: severity of exposure, history of prior stress exposure, and pre-existing mental disorders. The high concentration of PTSD among respondents with high predicted risk in our model supports the focus of screening assessments that identify disaster survivors most in need of preventive interventions.

Keywords

Disaster; post-traumatic stress disorder; PTSD

Introduction

Natural and human-made disasters are increasingly common occurrences around the globe (Lopes *et al.* 2014; Warsini *et al.* 2014). Systematic research on development of post-traumatic stress disorder (PTSD) following disasters has been undertaken for more than three decades, with most studies reporting only short-term consequences. Recent reviews suggest that between 20% (North, 2014) and 40% (Neria *et al.* 2008) of survivors develop PTSD, but the range across studies is extremely broad (5–60% following natural disasters; 25–75% following human-made disasters) (Galea *et al.* 2005) due to differences in the characteristics/locations of disasters and methodological differences in studies (Norris *et al.* 2006; Goldmann & Galea, 2014).

A handful of general population epidemiological surveys retrospectively assessed lifetime exposure to disasters and prevalence of post-disaster PTSD. The first such study, the National Comorbidity Survey (NCS; Kessler *et al.* 1995), found that much lower proportions of disaster survivors developed post-disaster PTSD (3.7% of men, 5.4% of women) than in disaster-focused studies. More recent community epidemiological surveys in Europe (Ferry *et al.* 2014; Olaya *et al.* 2015) and the United States (Breslau *et al.* 1998, 2013) found similar results. Importantly, PTSD prevalence estimates in these surveys were considerably higher for some other lifetime traumatic experiences (Molnar *et al.* 2001; Darves-Bornoz *et al.* 2008; Olaya *et al.* 2015), suggesting that the low post-disaster PTSD prevalence estimates were not due to recall bias. The discrepancy between these low prevalence estimates in representative community samples and much higher estimates in post-disaster surveys raises the question whether demand characteristics and unrepresentative samples led to upwardly biased estimates in post-disaster surveys (Bonanno *et al.* 2010).

We attempt to shed light on this question by presenting data on prevalence-correlates of disaster-related PTSD in the WHO World Mental Health (WMH) Surveys. Measures of severity of exposure to disaster-related stressors are among the strongest risk factors for PTSD in post-disaster surveys (Fergusson *et al.* 2014; Goldmann & Galea, 2014; Bromet *et al.* 2016). Other key risk factors include pre-disaster psychopathology, female gender, younger age at the time of the disaster, and early childhood adversity (Sayed *et al.* 2015). We use information about these potential predictors to examine PTSD prevalence and correlates among respondents in a series of WMH surveys who reported lifetime exposure to disasters.

Method and materials

Samples

Data come from the 18 WMH surveys that used an expanded assessment of PTSD (described below) to examine PTSD associated with *randomly selected* traumatic experiences (Table 1). These surveys included 10 in countries classified by The World Bank (2012) as high-income countries [national surveys in Belgium, France, Germany, Italy, The Netherlands, Northern Ireland, Spain, United States, along with regional surveys in Japan (a number of metropolitan areas) and Spain (Murcia)] and eight in countries classified as low-/middle-income countries (national surveys in Lebanon, Peru, Romania, South Africa, and Ukraine along with surveys of all non-rural areas in Colombia and Mexico and a separate regional survey in Medellin, Colombia). Each survey was based on a probability sample of household residents in the target population using a multi-stage clustered area probability design. Response rates had weighted averages of 84.7% in low-/lower-middle-income countries, 79.8% in upper-middle-income countries, 63.5% in high-income countries, and 70.3% overall. Four surveys had response rates below the minimally acceptable level of 60% (45.9% in France, 50.6% in Belgium, 55.1% in Japan, 56.4% in The Netherlands). A detailed description of sampling procedures is presented elsewhere (Heeringa *et al.* 2008).

Field procedures

Interviews were administered face-to-face in respondents' homes after obtaining informed consent using procedures approved by local Institutional Review Boards. The interview schedule was developed in English and translated into other languages using a standardized WHO translation, back-translation, and harmonization protocol (Harkness *et al.* 2008). Bilingual supervisors were trained and supervised by the WMH Data Collection Coordination Centre to guarantee cross-national consistency in field procedures (Harkness *et al.* 2008).

Interviews were conducted in two parts. Part I was administered to all respondents and assessed core DSM-IV mental disorders ($n = 73\,450$ respondents across all surveys). Part II assessed additional disorders and correlates. Questions about traumatic experiences and PTSD were included in Part II, which was administered to 100% of respondents who met lifetime criteria for any Part I disorder and a probability subsample of other Part I respondents ($n = 37\,255$). Part II respondents were weighted to adjust for differential probabilities of selection, selection into Part II, and deviations between the sample and population demographic-geographic distributions. More details about WMH weighting are presented elsewhere (Heeringa *et al.* 2008).

Measures

Exposure to traumatic experiences—Part II respondents were asked about lifetime exposure to each of 27 different types of traumatic experiences (TEs) in addition to two open-ended questions about exposure to '*any other*' TE and to a '*private*' TE the respondent did not want to name. Respondents were presented with a TE list and asked to report lifetime exposure to each type. Positive responses were followed by probes to assess the number of lifetime exposures and age at first exposure to each type. Missing values were rare because the surveys were interviewer-administered, but were coded conservatively as indicating that the TE did not occur. A total of $n = 14\,127$ respondents reported lifetime exposure to at least one TE. Exploratory factor analysis found six broad correlated groups of TEs: four of exposure to organized violence (e.g. civilian in a war zone, relief worker in a war zone, refugee); five related to participation in organized violence (e.g. combat experience, saw atrocities); three of exposure to interpersonal violence (witnessed violence at home as a child, beaten by a caregiver as a child, beaten by someone else other than a romantic partner); seven related to sexual violence (e.g. raped, sexually assaulted, beaten by a romantic partner); six of accidents/injuries (e.g. natural disaster, toxic chemical exposure, motor vehicle accident); and a final three not strongly correlated with other TEs (mugged or threatened with a weapon, exposure to a human-made disaster other than toxic chemical exposure, unexpected death of someone close) (Benjet *et al.* 2016).

Randomly selected traumatic experiences—One lifetime occurrence of one reported TE type was selected randomly for each respondent for more detailed assessment. Once this occurrence was selected, a short set of TE-specific questions was asked about characteristics of the randomly selected TE. PTSD in the wake of that occurrence was then assessed. The TE question about natural disasters was '*Were you ever involved in a major natural disaster, like a devastating flood, hurricane, or earthquake?*' The comparable question for human-made disasters was '*Were you ever in a man-made disaster, like a fire started by a cigarette, or a bomb explosion?*' When either of these was the randomly selected TE, four additional TE-specific questions were asked: whether the respondent was seriously injured in the disaster; whether the respondent was displaced (i.e. forced to leave their home) by the disaster; whether anyone close to the respondent was seriously injured or died in the disaster; and whether the respondent witnessed anyone die during the disaster.

Post-disaster PTSD assessment—PTSD in the wake of the randomly selected TE was assessed with the PTSD section of the Composite International Diagnostic Interview (CIDI; Kessler & Ustun, 2004), a fully structured interview administered by trained lay interviewers. DSM-IV criteria were used. Criterion A1 (exposure to an experience involving threatened death or serious injury) was assumed to exist by virtue of endorsing the TE question. Criterion A2 (intense, fear, helplessness, or horror) was not required, but Criteria B (persistent re-experiencing), C (avoidance-numbing), D (increased arousal), E (minimum duration of more than 1 month), and E (clinically significant distress or impairment) were all required. As detailed elsewhere (Haro *et al.* 2006), blinded clinical reappraisal interviews with the Structured Clinical Interview for DSM-IV (SCID) conducted in four WMH countries found CIDI-SCID concordance for DSM-IV PTSD to be moderate (Landis & Koch, 1977) (AUC = 0.69). Sensitivity and specificity were 0.38 and 0.99, respectively, resulting in a positive likelihood ratio (LR+) of 42.0, which is well above the threshold of 10 typically used to consider screening scale diagnoses definitive (Gardner & Altman, 2000). Consistent with the high LR+, the proportion of CIDI cases confirmed by the SCID was 86.1%. This means the vast majority of CIDI/DSM-IV PTSD cases would independently be confirmed by a blinded trained clinician. Missing symptom reports, which were rare, were coded conservatively as the symptoms being absent.

Other mental disorders—The CIDI was also used to assess 14 prior (to the respondent's age of exposure to the randomly selected TE) lifetime DSM-IV mental disorders, including two mood disorders [major depressive disorder/dysthymic disorder and broadly defined bipolar disorder (BPD; including BP-I, BP-II, and subthreshold BPD defined using criteria described elsewhere [Kessler *et al.* 2006])], six anxiety disorders [panic disorder with or without agoraphobia, specific phobia, social phobia, generalized anxiety disorder, prior (to the randomly selected TE) PTSD, and separation anxiety disorder], four disruptive behaviour disorders (attention deficit hyperactivity disorder, oppositional-defiant disorder, conduct disorder, and intermittent explosive disorder), and two substance disorders (alcohol abuse with or without dependence, drug abuse with or without dependence). Age-of-onset (AOO) of each disorder was assessed using special probing techniques shown experimentally to improve recall accuracy (Knauper *et al.* 1999) allowing us to determine, using retrospective AOO reports, whether each respondent had a history of each disorder prior to occurrence of the randomly selected TE. DSM-IV organic exclusion rules and diagnostic hierarchy rules were used (other than ODD, which was defined with or without CD, and substance abuse, which was defined with or without dependence). As detailed elsewhere (Haro *et al.* 2006), generally good concordance was found between these CIDI diagnoses and blinded clinical diagnoses based on SCID clinical reappraisal interviews (First *et al.* 1994). Missing symptom reports, which were rare, were coded conservatively as the symptoms being absent. Missing information on AOO, which was rare, was imputed using regression-based imputation.

Other predictors of post-disaster PTSD—We examined four classes of predictors in addition to disaster characteristics and respondent history of psychopathology. The first were socio-demographics: age, education, and marital status, each defined as of the time of the disaster, and sex. Given its wide variation across countries, education was classified as low, low-average, high-average, or high (coded as a continuous 1–4 score) according to within-country norms. Details on this coding scheme are described elsewhere (Scott *et al.* 2014). Missing values, which were rare, were imputed using regression-based imputation. The next three classes of predictors assessed whether the respondent had been in one or more previous disasters, exposure to other lifetime TEs, and exposure to childhood family adversities (CAs). Consistent with prior WMH research (Kessler *et al.* 2010), we distinguished between CAs in a highly correlated set of seven we labelled Maladaptive Family Functioning (MFF) CAs (parental mental disorder, parental substance abuse, parental criminality, family violence, physical abuse, sexual abuse, neglect) and other CAs (parental divorce, parental death, other parental loss, serious physical illness, family economic adversity). Details on CA measurement are presented elsewhere (Kessler *et al.* 2010). CAs that were examples of broader classes of TEs (e.g. sexual assaults perpetrated by a family member *v.* other sexual assaults) were included both in the TE inventory and the CA inventory in order to evaluate the incremental importance of exposure in the family context. Missing CA reports, which were rare, were coded conservatively as the CAs being absent.

Analysis methods

Each randomly-selected TE occurrence was weighted by the inverse of its probability of selection. For example, a respondent who reported three TE types and two occurrences of the randomly selected type would receive a TE weight of 6.0. The product of the Part II weight with the TE weight was used in our analyses, yielding a sample representative of all lifetime TEs occurring to all respondents. The sum of the consolidated weights across these respondents was standardized within each country to the observed number of respondents with the randomly selected disaster for purposes of pooled cross-national analysis.

Logistic regression was used to examine predictors of post-disaster PTSD pooled across surveys. Predictors were entered in blocks, beginning with socio-demographics, followed by disaster characteristics, prior TE and CA exposure, and prior mental disorders. All models included dummy control variables for surveys. Logistic regression coefficients and standard errors were exponentiated and are reported as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance of individual ORs was evaluated using 0.05-level two-sided tests based on the design-based Taylor-series method (Wolter, 1985) implemented in the SAS software system (SAS Institute Inc., 2008). Design-based F tests were used to evaluate significance of predictor sets, with numerator degrees of freedom equal to number of predictors and denominator degrees of freedom equal to number of geographically clustered sampling error calculation units containing randomly selected disasters across surveys (n = 138), minus the sum of primary sample units from which these sampling error calculation units were selected (n = 100) and one less than the number of variables in the predictor set (Reed, 2007), resulting in 38 denominator degrees of freedom in evaluating univariate predictions and fewer in evaluating multivariate predictions.

Once the final model was estimated, a predicted probability of PTSD was generated for each respondent from model coefficients. A receiver-operating characteristic (ROC) curve was calculated from these predicted probabilities (Zou *et al.* 2007) and area under the ROC curve (AUC) was calculated to quantify overall prediction accuracy (Hanley & McNeil, 1983). We then evaluated sensitivity and positive predictive value among the 5% of respondents with highest predicted probabilities to determine how well the model implies that subsequent PTSD could be predicted if the model was applied in the immediate aftermath of a future disaster. Sensitivity was the proportion of observed PTSD cases found among the 5% of respondents with highest predicted probabilities. Positive predictive value was the prevalence of PTSD among this 5% of respondents. We used the method of replicated 10-fold cross-validation with 20 replicates (i.e. 200 separate estimates of model coefficients) to correct for the over-estimation of prediction accuracy when both estimating and evaluating model fit in a single small sample (Smith *et al.* 2014).

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Results

Prevalence of disaster-related PTSD

Disaster exposure was the randomly selected TE for 661 respondents across the 18 surveys (Table 2). In 10 surveys, none of the respondents met DSM-IV/CIDI criteria for PTSD, while in the remaining eight surveys mean weighted PTSD prevalence was 2.5% (18 observed PTSD cases across surveys). Six of the latter eight surveys (accounting for 86.3% of respondents across all eight) were done in high-income countries and the other two in low-/middle-income countries. PTSD prevalence estimates were, on average, higher in the surveys in high- than low-/middle-income countries (2.8% *v.* 0.4%; $t = 1.9$, $p = 0.051$).

Predictors of disaster-related PTSD

The number of respondents with disaster-related PTSD in the two low-/middle-income countries was too small ($n = 2$ of $n = 60$ respondents) to estimate logistic regression equations separately. We consequently excluded low-/middle-income countries from further analysis. Median (interquartile range) number of years between the index disaster and the WMH interview in the remaining 6 surveys was 14 (3–35) years.

Model 1—Although respondent's age and education at time of disaster both had significant positive univariate associations with disaster-related PTSD (age: OR 1.2, 95% CI 1.0–1.4; education: OR 2.1, 95% CI 1.1–3.9), neither association remained significant in the multivariate model (model 1) (Table 3). A methodological control for number of years between respondent's age at disaster and age at interview to investigate the possibility of time-related recall bias added to the model was non-significant (OR 1.4, 95% CI 0.8–2.2).

Model 2—Human-made disasters (reported by 26.6% of respondents) were associated with significantly higher odds of PTSD than natural disasters (OR 3.3, 95% CI 1.1–9.7) in the multivariate model of disaster characteristics (model 2). Serious injury or death of someone close (reported by 4.3% of respondents) was also a significant predictor (OR 21.5, 95% CI 2.1–222.8), although the wide CI and much higher OR than in the univariate model signalled model instability. Being displaced by the disaster (reported by 27.8% of respondents) was also a significant predictor in the multivariate model (OR 6.6, 95% CI 1.9–22.3) even though it was not significant in the univariate model. Serious injury to the respondent (reported by 1.1% of respondents), while a significant univariate predictor, was not significant in the multivariate model. Finally, the respondent witnessing death (reported by 7.8% of respondents) was not a significant univariate or multivariate predictor.

Model 3—Preliminary analysis of associations of prior TEs with disaster-related PTSD showed prior TEs involving exposure to sectarian, interpersonal, or sexual violence were the only ones consistently associated with increased risk of disaster-related PTSD controlling model 3 predictors. (See supplementary material.) The most parsimonious characterization of these associations used a single dichotomous variable for whether the respondent was previously exposed to any such TE (reported by 25.1% of respondents; OR 16.4, 95% CI 2.6–101.6). Preliminary analysis of the associations of CAs with disaster-related PTSD showed numerous significant positive univariate associations that could best be summarized with a 0–3+ count for number of MFF CAs (15.4%, 1; 6.5%, 2; 13.3% 3+; OR 2.9, 95% CI 1.4–6.2). (See supplementary material.) The multivariate ORs of both TEs and CAs were larger than the univariate ORs and had wide CIs. In addition, the OR of serious injury/death of someone close became markedly higher in model 3 than model 2.

Model 4—Preliminary analysis showed that 13 of the 14 temporally primary lifetime DSM-IV/CIDI disorders had elevated univariate ORs predicting disaster-related PTSD (11 of them significant at the 0.05 level), but that only a handful were significant in a multivariate model due to high co-morbidity. (See supplementary material online.) The most parsimonious characterization of these associations used dummy variables for exactly 1 (17.6%, OR 9.8, 95% CI 0.5–192.4) and 2+ (14.1%, OR 60.0, 95% CI 21.1–170.5) prior lifetime DSM-IV/CIDI disorders as predictors. The significant OR of prior lifetime TEs in model 3 decreased substantially, while the significant OR of serious injury or death of someone close to the respondent increased substantially when mental disorders were controlled in model 4 compared to model 3.

Strength and consistency of overall model predictions

Although the small sample size precluded estimating model coefficients separately in each survey, we could compare overall model fit in subsamples by calculating individual-level predicted probabilities from model 4 with 20 replicates of 10-fold cross-validation, estimating subsample ROC curves from these predicted probabilities, and calculating AUC based on these curves. Estimated AUC based on 20 replicates of 10-fold cross-validated predictions was 0.63 in the total sample and 0.48–0.75 in subsamples defined by respondent's sex, age, and education. These are weak to intermediate levels of overall classification accuracy (Roemer *et al.* 1998). However, the 5% of respondents with highest predicted probabilities of PTSD included a substantial proportion (44.5%) of all disaster-related PTSD (sensitivity) in the total sample. This is nine times the concentration of risk expected by chance (Table 4). Subgroup sensitivities among this 5% of respondents with highest predicted risk ranged from 56.4% among men to 22.4% among respondents with low-average/low education. Positive predictive value (the proportion of predicted positives who met criteria for PTSD) among the 5% of respondents with higher predicted risk was 20.4% in the total sample and between 39.5% among respondents with high-average/high education to 3.9% among respondents with low-average/low education (Fig. 1).

Discussion

Several limitations should be noted. First, several surveys had unacceptably low response rates. Second, TEs and mental disorders were assessed retrospectively, although special recall probes used in WMH surveys have been shown experimentally to improve retrospective recall accuracy (Knauper *et al.* 1999). Third, diagnoses were based on a fully structured lay-administered interview rather than semi-structured clinical interviews, although WMH clinical appraisal data are reassuring (Haro *et al.* 2006). Fourth, given that disasters were only one of many TEs assessed in the WMH surveys, information on potentially important predictors of post-disaster PTSD was much more limited than in surveys focused exclusively on disaster survivors.

The sampling restrictions are of special importance. The vast majority of disasters occur in low- and middle-income countries (Roy *et al.* 2011), but our analyses were carried out exclusively in high-income countries. In addition, the samples were restricted to household residents. This means that we excluded people living in displacement camps and other group quarters, which is an especially serious limitation given that displacement was a significant predictor of disaster-related PTSD. While the 378 respondents assessed for randomly selected disasters is sufficient to estimate prevalence of post-disaster PTSD with good precision, the fact that PTSD was an uncommon outcome ($n = 16$) meant that we lacked statistical power to estimate multivariate predictor coefficients with precision. Indeed, with 13 model coefficients, the 1.2 events-per-variable (EPV) ratio was well below the value recommended to avoid biased OR estimates (Peduzzi *et al.* 1996). Caution is consequently needed in interpreting our results because of low EPV and the clear evidence of model instability noted in Table 3.

Despite these limitations, our study is valuable in providing the first cross-national data on prevalence of disaster-related PTSD among household residents. Results are clear across countries that post-disaster PTSD is uncommon. This is consistent with previous general population surveys on post-disaster PTSD in Europe (Ferry *et al.* 2014; Olaya *et al.* 2015) and the United States (Kessler *et al.* 1995; Breslau *et al.* 1998, 2013). As noted in the Introduction, disaster-focused studies, which are typically carried out between 1 month and 2 years after disasters, generally yield considerably higher prevalence estimates, presumably because of unrepresentative samples and demand characteristics, although another consideration is that these studies tend to be carried out primarily in conjunction with the most severe disasters.

The most important predictors in our study were generally consistent with those found in previous post-disaster studies (Galea *et al.* 2005): prior psychopathology, disaster severity, and history of previous trauma. This adds support to the recommendation of North & Pfefferbaum (2013) to include information about these three classes of risk factors in needs assessment surveys of disaster survivors. It is also noteworthy that several previous epidemiological studies found, consistent with our result, that human-made disasters have more pernicious psychological effects than natural disasters (Galea *et al.* 2005), although this association became much less pronounced when we controlled for disaster-related characteristics, suggesting that at least part of the reason human-made disasters are associated with higher rates of PTSD than natural disasters is that the former are objectively more severe. Caution is needed in interpreting this result, though, as an exploratory factor analysis of TEs in an earlier WMH report found that the human-made disasters reported in the WMH surveys include a mix of accidents caused by human error and motivated acts of terrorism (Benjet *et al.* 2016). We have no way of distinguishing these two types of human-made disasters to determine if they have similar associations with PTSD.

Perhaps our most striking result was that nearly half of disaster-related PTSD occurred among the 5% of respondents with highest predicted risk scores in our model. This result is broadly consistent with several other recent studies showing that subsequent PTSD can be predicted with good accuracy using data collected in the immediate aftermath of trauma about pre-trauma risk factors, objective trauma characteristics, and early post-traumatic responses (Galatzer-Levy *et al.* 2014; Kessler *et al.* 2014; Karstoft *et al.* 2015). These findings contradict the previously-held view that the individual predictors in epidemiological models of PTSD have ORs too weak and inconsistent to be clinically useful in targeting people for preventive interventions (Brewin, 2005a), making it necessary to use assessment tools in the aftermath of trauma focused on current symptoms rather than risk factors (Brewin, 2005b). The error in this earlier way of thinking was in failing to appreciate that multivariate model-based predictions can be strong even when coefficients of individual predictors are weak. It is noteworthy in this regard that our high concentration of PTSD risk among the 5% of respondents with highest predicted risk from our model was based on a replicated cross-validated simulation designed to adjust for over-fitting due to low EPV.

The evidence we found for high concentration of risk based on our model suggests that future research is needed both to create an assessment tool for use in the aftermath of disasters to measure key risk factors (i.e. disaster-related experiences, prior exposures to highly stressful experiences, and prior history of mental disorders) and to develop a prediction model that uses this information to generate individual-level PTSD risk scores to target high-risk survivors for preventive interventions. While the WMH results provide strong suggestive evidence that a useful model of this sort could be developed from self-report data, the WMH model itself is inadequate because it was based on coarse measures assessed retrospectively in a small sample.

At the same time, the WMH results were sufficiently consistent with prior evidence that one could imagine a triage screening system being developed that was based loosely on these consistent risk factors. This is the approach taken in the PsySTART system recently adopted by the American Red Cross to target rapid delivery of psychological first aid and referral for mental health services to disaster survivors judged to be at high risk of post-disaster mental disorders in the immediate aftermath of a disaster (Schreiber *et al.* 2014). PsySTART is different from previous post-disaster risk evaluation schemes in that it does not focus on current psychological distress (other than acute suicidality), which is an unreliable predictor of post-disaster mental disorders (Norris *et al.* 2002), but on evidence-based predictors of those disorders (disaster-related experiences, prior disaster exposure, prior trauma exposure, and history of prior mental disorders) evaluated by trained Red Cross disaster mental health workers.

The approach proposed here could be seen as a next step in the PsySTART program designed to refine the selection of risk factors and optimize the weighting scheme used to combine information about these risk factors into a composite risk score. These refinements would require data to be collected from a much larger sample than in the WMH analysis. The sample should include a baseline assessment of a broad range of risk factors obtained in the immediate aftermath of disaster. Participants should be followed over time to determine who develops PTSD or other post-disaster mental disorders. Much more sophisticated data analysis methods should be used to analyse these data than in the WMH analysis. In particular, machine learning methods designed to maximize out-of-sample prediction accuracy should be used to develop the final model (Kessler *et al.* 2014), leading to optimal selection of the risk factors to include in subsequent assessments and to optimal weighting of these measures to assess risk of post-disaster psychopathology. We were unable to use these methods in the WMH analysis because of our small sample size. Given the growing literature documenting the value of interventions in the immediate aftermath of trauma (Forneris *et al.* 2013; Kliem & Kroger, 2013; Amos *et al.* 2014; Bisson, 2014), the development of such an optimal prediction model could be of great practical value.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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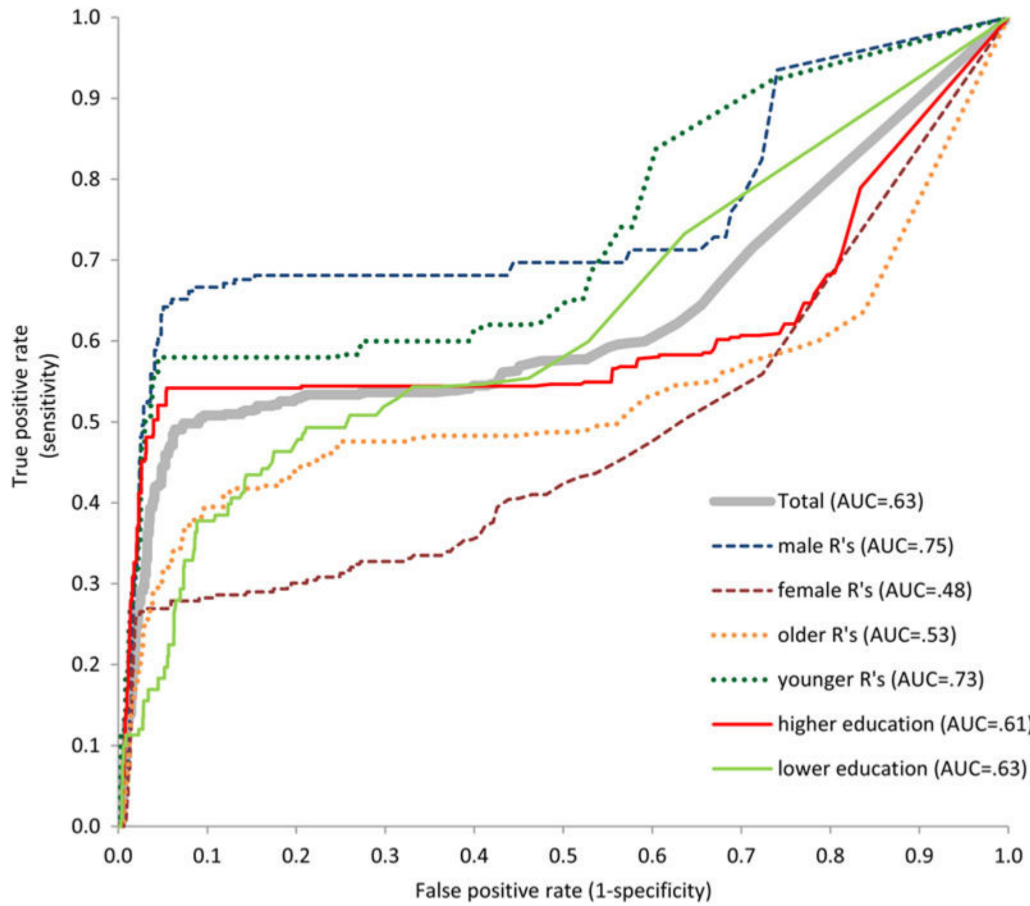

Fig. 1.

Area under the curve (AUC) of predicted probabilities based on model 4 overall and in selected subgroups.

Table 1

World Mental Health (WMH) sample characteristics by World Bank income categories[a]

	Survey[b]	Sample characteristics[c]	Field dates	Age range	Sample size Part I	Sample size Part II	Response rate[d]
I. Low- and lower-middle-income countries							
Colombia	NSMH	All urban areas of the country (~73% of the total national population)	2003	18–65	4426	2381	87.7
Peru	EMSMP	Nationally representative	2004–2005	18–65	3930	1801	90.2
Ukraine	CMDPSD	Nationally representative	2002	18–91	4725	1720	78.3
Total					13 081	5902	84.7
II. Upper-middle-income countries							
Colombia – Medellin[e]	MMHHS	Medellin metropolitan area	2011–2012	19–65	3261	1673	97.2
Lebanon	LEBANON	Nationally representative	2002–2003	18–94	2857	1031	70.0
Mexico	M-NCS	All urban areas of the country (~75% of the total national population)	2001–2002	18–65	5782	2362	76.6
Romania	RMHS	Nationally representative	2005–2006	18–96	2357	2357	70.9
South Africa[f]	SASH	Nationally representative	2003–2004	18–92	4315	4315	87.1
Total					18 572	11 738	79.8
III. High-income countries							
Belgium	ESEMeD	Nationally representative, sample selected from a national register of Belgium residents	2001–2002	18–95	2419	1043	50.6
France	ESEMeD	Nationally representative, sample selected from a national list of households with listed telephone numbers	2001–2002	18–97	2894	1436	45.9
Germany	ESEMeD	Nationally representative	2002–2003	19–95	3555	1323	57.8
Italy	ESEMeD	Nationally representative, sample selected from municipality resident registries	2001–2002	18–100	4712	1779	71.3
Japan	WMHJ 2002–2006	Eleven metropolitan areas	2002–2006	20–98	4129	1682	55.1
Netherlands	ESEMeD	Nationally representative, sample selected from municipal postal registries	2002–2003	18–95	2372	1094	56.4
N. Ireland	NISHS	Nationally representative	2004–2007	18–97	4340	1986	68.4
Spain	ESEMeD	Nationally representative	2001–2002	18–98	5473	2121	78.6
Spain – Murcia	PEGASUS-Murcia	Murcia region	2010–2012	18–96	2621	1459	67.4
United States	NCS-R	Nationally representative	2002–2003	18–99	9282	5692	70.9
Total					41 797	19 615	63.5

	Survey[b]	Sample characteristics[c]	Field dates	Age range	Sample size		Response rate[d]
					Part I	Part II	
IV. Total					73 450	37 255	70.3

[a]The World Bank (2012) data. Accessed 12 May 2012 at: http://data.worldbank.org/country. Some of the WMH countries have moved into new income categories since the surveys were conducted. The income groupings above reflect the status of each country at the time of data collection. The current income category of each country is available at the preceding URL.

[b]NSMH (The Colombian National Study of Mental Health); EMSMP (La Encuesta Mundial de Salud Mental en el Peru); CMDPSD (Comorbid Mental Disorders during Periods of Social Disruption); MMHHS (Medellín Mental Health Household Study); LEBANON (Lebanese Evaluation of the Burden of Ailments and Needs of the Nation); M-NCS (The Mexico National Comorbidity Survey); RMHS (Romania Mental Health Survey); SASH (South Africa Health Survey); ESEMeD (The European Study Of The Epidemiology Of Mental Disorders); WMHJ 2002–2006 (World Mental Health Japan Survey); NISHS (Northern Ireland Study of Health and Stress); PEGASUS-Murcia (Psychiatric Enquiry to General Population in Southeast Spain-Murcia); NCS-R (The US National Comorbidity Survey Replication)

[c]Most WMH surveys are based on stratified multistage clustered area probability household samples in which samples of areas equivalent to counties or municipalities in the United States were selected in the first stage followed by one or more subsequent stages of geographic sampling (e.g. towns within counties, blocks within towns, households within blocks) to arrive at a sample of households, in each of which a listing of household members was created and one or two people were selected from this listing to be interviewed. No substitution was allowed when the originally sampled household resident could not be interviewed. These household samples were selected from Census area data in all countries other than France (where telephone directories were used to select households) and The Netherlands (where postal registries were used to select households). Several WMH surveys (Belgium, Germany, Italy) used municipal resident registries to select respondents without listing households. The Japanese sample is the only totally unclustered sample, with households randomly selected in each of the 11 metropolitan areas and one random respondent selected in each sample household. Thirteen of the 18 surveys are based on nationally representative household samples

[d]The response rate is calculated as the ratio of the number of households in which an interview was completed to the number of households originally sampled, excluding from the denominator households known not to be eligible either because of being vacant at the time of initial contact or because the residents were unable to speak the designated languages of the survey. The weighted average response rate is 70.3%.

[e]Colombia moved from the 'lower and lower-middle-income' to the 'upper-middle-income' category between 2003 (when the Colombian National Study of Mental Health was conducted) and 2010 (when the Medellin Mental Health Household Study was conducted), hence Colombia's appearance in both income categories. For more information, please see Table note a.

[f]For the purposes of cross-national comparisons we limit the sample to those aged 18+.

Table 2

Prevalence of DSM-IV/CIDI disaster-related PTSD among respondents with randomly selected disasters by survey (n = 438)[a]

	% PTSD	(95% CI)	Number with PTSD (n_1)[b]	Total sample size (n_2)[b]
I. High-income countries				
Belgium	0.5	(0.0–1.7)	(1)	(7)
Italy	3.8	(0.0–11.2)	(1)	(35)
Northern Ireland	0.5	(0.0–1.5)	(1)	(23)
Spain	0.1	(0.0–0.2)	(1)	(14)
Spain – Murcia	2.6	(0.0–5.4)	(9)	(141)
United States	3.4	(0.0–8.0)	(3)	(158)
Total high	2.8	(0.5–5.1)	(16)	(378)
χ^2_5[c]	3.9		$p = 0.57$	
II. Middle- and low-income countries				
Colombia	0.5	(0.0–1.5)	(1)	(21)
Mexico	0.3	(0.0–0.9)	(1)	(39)
Total low or middle	0.4	(0.0–0.9)	(2)	(60)
χ^2_1[c]	0.1		$p = 0.73$	
III. All countries	2.5	(0.5–4.4)	(18)	(438)
Overall between country difference – χ^2_7[c]	5.0		$p = 0.67$	
High *v.* low or middle difference – χ^2_1[c1]	3.5		$p = 0.06$	

PTSD, Post-traumatic stress disorder; CI, confidence interval.

[a]Each respondent who reported lifetime exposure to one or more traumatic experiences (TEs) had one occurrence of one such experience selected at random for detailed assessment. Each of these randomly selected TEs was weighted by the inverse of its probability of selection at the respondent level to create a weighted sample of TEs that was representative of all TEs in the population. The randomly selected disasters were the subset of these randomly selected TEs involving either natural or human-made disasters. The sum of weights of the randomly selected disasters was standardized within surveys to sum to the observed number of respondents whose randomly selected TE was a disaster. The *n* reported in the last column of this table represents that number of respondents. The results reported here are for the surveys where at least one respondent with a randomly selected disaster met DSM-IV/CIDI criteria for PTSD related to that TE. None of the respondents with randomly selected disasters in the other WMH surveys met criteria for disaster-related PTSD. These included 21 respondents in France 13 in Germany, 21 in Japan, 19 in Lebanon, 26 in Medellin, 11 in The Netherlands, 39 in Peru, 29 in Romania, 29 in South Africa, and 15 in Ukraine.

[b]The reported sample sizes are unweighted. The unweighted proportions of respondents with PTSD do not match the prevalence estimates in the first column because the latter were based on weighted data.

[c]The χ^2 test with 5 degrees of freedom (df) in Part I of the table evaluated the significance of prevalence differences across the six high-income countries, while the 1 df test in Part II evaluated the prevalence difference between the two middle- and low-income countries. The two χ^2 tests in Part III evaluated the significance of prevalence differences across all countries (the 7 df test) and between high- and middle-/low-income countries (the 1 df test). None of the tests are significant at the 0.05 level.

Table 3

Associations of socio-demographics, disaster characteristics, and prior vulnerabilities with DSM-IV/CIDI disaster-related PTSD (n = 378)[a]

	Univariate Model[b]		Model 1		Model 2		Model 3		Model 4	
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
I. Socio-demographics										
Age at disaster (in decades)	1.2*	(1.0–1.4)	1.4	(0.9–2.1)	1.8	(1.0–3.2)	1.4	(0.7–2.6)	0.9	(0.3–3.0)
Gender (female)	1.0	(0.3–4.1)	1.4	(0.3–5.6)	0.9	(0.2–3.8)	1.4	(0.5–3.5)	0.9	(0.3–2.8)
Education[c]	2.1*	(1.1–3.9)	2.7	(0.9–8.0)	2.7	(0.7–10.8)	3.2	(0.8–12.4)	2.5*	(1.5–4.2)
Ever married	0.8	(0.2–2.8)	0.2	(0.0–3.9)	0.1	(0.0–1.3)	0.2*	(0.0–0.6)	0.2	(0.0–1.2)
II. Disaster characteristics										
Human-made *v.* natural disaster	5.3*	(1.4–19.3)	–	–	3.3*	(1.1–9.7)	2.9*	(1.3–6.7)	3.1	(0.9–10.0)
Serious injury to respondent	8.6*	(2.2–33.9)	–	–	0.6	(0.1–3.0)	0.6	(0.1–6.6)	0.3	(0.0–2.4)
Respondent witnessed death	6.4	(0.4–108.2)	–	–	1.3	(0.0–57.0)	1.2	(0.2–6.6)	0.3	(0.1–1.5)
Serious injury/death of loved one	15.3*	(1.6–143.1)	–	–	21.5*	(2.1–222.8)	88.2*	(13.0–596.7)	165.9*	(26.7–1031.0)
Respondent displaced from home	4.3	(0.8–22.9)	–	–	6.6*	(1.9–22.3)	9.3*	(5.1–16.9)	6.2*	(3.2–12.2)
III. Prior vulnerability actors										
Any prior traumatic violent experience[d]	7.7*	(3.3–18.0)	–	–	–	–	16.4*	(2.6–101.6)	5.0*	(1.2–21.5)
Count of childhood adversities[e]	2.2*	(1.2–4.0)	–	–	–	–	2.9*	(1.4–6.2)	3.6*	(2.0–6.7)
Prior mental disorders										
Exactly 1	1.7	(0.5–6.5)	–	–	–	–	–	–	9.8	(0.5–192.4)
2+	38.4*	(15.5–95.0)	–	–	–	–	–	–	60.0*	(21.1–170.5)
$F_{(2,37)}$[f]	214.1*	$p < 0.001$	–	–	–	–	–	–	52.5*	$p < 0.001$
$F_{(5,35), (9,30), (11,28), (13,26)}$[g]	–	–	1.9	$p = 0.14$	72.3*	$p < 0.001$	69.9*	$p < 0.001$	133.1*	$p < 0.001$

PTSD, Post-traumatic stress disorder; OR, Odds ratio; CI, confidence interval.

[a]All models were estimated in weighted data pooled across the six surveys in high-income countries. See Table note a in Table 2 for a description of the weighting. All models included dummy variable controls for surveys. This means that the reported ORs should be interpreted as pooled within-survey coefficients.

[b]The univariate associations are based on a separate model for each row, with the variable in the row and the dummy controls for survey the only predictors in the model.

[c]Education was treated as a continuous variable coded 1–4 (low, low-average, high-average, high).

[d]Any prior traumatic violent experience includes exposure to any of four types of organized violence (e.g. civilian in a war zone, relief worker in a war zone, refugee); three types of interpersonal violence (witnessed violence at home as a child, beaten by a caregiver as a child, beaten by someone else other than a romantic partner); and seven types of sexual violence (e.g. raped, sexually assaulted, beaten by a romantic partner).

[e]A count in the range 0–3+ of maladaptive family functioning childhood adversities experienced by the respondent in childhood from a total of seven assessed in the surveys that included parental mental disorder, parental substance abuse, parental criminality, family violence, physical abuse, sexual abuse, and physical neglect.

[f]The joint significance of the pair of dummy variables for number of mental disorders.

[g]The joint significance of all variables in the model. The numerator and denominator degrees of freedom are, respectively, the number of predictors in the model and the residual number of sampling error calculation units.

[*]Significant at the 0.05 level, two-sided test.

Table 4

Concentration of risk of observed post-traumatic stress disorder (PTSD) in the top 5th percentile of predicted PTSD, total sample and stratified by subgroups (n = 378)[a]

	Sensitivity[b]		Positive predictive value[c]	
	% PTSD	**(S.E.)**	**% PTSD**	**(S.E.)**
Total	44.5	(18.0)	20.4	(9.5)
Age				
25+ years	34.0	(13.6)	11.8	(1.3)
<25 years	52.9	(26.3)	32.4	(20.7)
Gender				
Male	56.4	(24.3)	29.4	(19.6)
Female	27.9	(23.8)	10.9	(8.8)
Education				
High or high-average	50.3	(20.3)	39.5	(16.4)
Low or low-average	22.4	(14.9)	3.9	(0.5)

[a]Based on weighted data pooled across the six surveys in high-income countries. See Table note a in Table 2 for a description of the weighting. Ten-fold cross-validation involves dividing the sample into 10 separate random subsamples of equal size, estimating the model in each of the 10 separate 90% subsamples created by deleting one of the 10 subsamples, and applying predicted values based on each set of coefficients only to the remaining 10% of the sample. Replicated cross-validation involves repeating the cross-validation process some number of times (20 times in the current application), with a different random split of the sample into 10 equal-sized subsamples each time. Sensitivity and positive predictive value were calculated separately in each of these 200 subsamples and averaged to produce the results reported here.

[b]Sensitivity = proportion of all PTSD found among the 5% of respondents with highest predicted probabilities based on the final model.

[c]Positive predictive value = prevalence of PTSD among respondents in the row who are among the 5% in the total sample with the highest predicted probabilities based on the final model.