Title: Association of mental disorders with firearm suicides: a systematic review with meta-analyses of observational studies in the United States

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Highlights

- More than half of all suicides are committed using a firearm in the United States.
- The association between mental health and the risk of firearm-related suicide has not been previously explored.
- Meta-analyses showed that mental health disorder was not associated with greater odds of committing suicide using a firearm.
- Risk of bias revealed a heterogeneous and poor definition of mental disorders as well as lack of control for potential demographic confounding factors.
Abstract

Background: In the United States, 61% of all suicide cases may involve firearms, and some evidence suggests that mental disorders may play a role in suicide by firearm. We performed the first systematic review and meta-analysis to investigate: (i) whether mental disorders are associated with suicide by firearm, and (ii) whether the risk of using a firearm compared with alternative means is associated with higher levels of suicide in individuals with a mental disorder. Methods and findings: We searched twelve databases from inception to the 24th of May 2020. We retrieved 22 observational studies conducted in the US. Random-effects meta-analysis showed individuals who had a diagnosis of a mental disorder had lower odds (odds ratios (OR)= 0.50, 95% CI: 0.36 to 0.69; $I^2$=100 (95% CI: 87 to 100%), of dying by suicide with a firearm than those who did not have a diagnosis of a mental disorder. Secondary analysis showed that decedents who had a mental health diagnosis resulted in lower odds of dying by suicide by using firearms than using other means. Limitations: Risk of bias revealed a heterogeneous and poor definition of mental disorders as well as lack of control for potential demographic confounding factors. In the meta-analysis, studies were combined in the same analytic sample as 77% of these studies did not specify the type of mental disorder. Conclusion: While our results seem to suggest that having a mental disorder may not be consistently associated with the odds of dying by suicide using a firearm, the presence of substantial heterogeneity and high risk of bias precludes any firm conclusions.

Keywords: mental health, depression, suicide, firearms, systematic review, meta-analysis

1. Introduction

Suicide is a major cause of preventable deaths worldwide (Naghavi, 2019), and it refers to a deliberate act against oneself with the intention or expectation of dying (Andriessen, 2006; Gulati et al., 2013). In the United States (US), suicide rates have risen 33% since 1999, increasing from 10.5 to 14 suicides per 100,000 people (Hedegaard, 2018), with almost
45,000 people dying by suicide in 2016 (Stone et al., 2018). Overall, suicide is the 11th leading cause of death in the US (Ahmad and Anderson, 2021) and the societal cost burden for suicidal behavior reaches around $70 billion per year based on lifetime medical costs and lost productivity (CDC, 2019; Corso et al., 2007; Shepard et al., 2016).

The underlying mechanisms of suicide have been extensively researched (Chesney et al., 2014; O’Connor and Nock, 2014; Shepard et al., 2016). The evidence suggests that a combination of biopsychosocial factors contribute to its completion (O’Connor and Nock, 2014). For example, some genetic predispositions to depressive symptoms (Maciejewski et al., 2017) may contribute to suicidal behavior traits (e.g. suicidal thoughts, plans, and attempts) independently of the genetic heritage of the psychiatric disorders (Voracek and Loibl, 2007). Psychosocial stressors, such as sexual assault or combat-related trauma, feature in major theories of suicide (Liu and Miller, 2014). Recently, a review found consistent associations between stress (e.g., acute life events, chronic difficulties, trauma) and suicidal ideation and behavior in adolescents and adults (Liu and Miller, 2014; Stewart et al., 2019). Behaviors such as excessive alcohol or drug use may also place an individual at a higher risk of suicide (Branas et al., 2016b; Wilcox et al., 2004) because aggression and impulsivity increase the risk for suicidal behavior among persons with alcohol and substance abuse (Sher, 2005). Presence of a mental disorder (O’Connor and Nock, 2014), particularly a mood, psychotic, or personality disorder is also linked with increased risk of suicide (Chesney et al., 2014; Too et al., 2019). However, while mental disorders are associated with greater suicide risk, not all individuals with a diagnosis of a mental disorder will engage in suicidal behavior (Joiner et al., 2017) and not all individuals who died by suicide carried a diagnosis of a mental disorder prior to suicide (Haw and Hawton, 2015).

The mode of suicide is also a relevant factor in the link between some mental disorders and suicide (Kaplan et al., 2012). Certain suicide methods such as firearms carry greater lethality
than other methods, including hanging, suffocation, and poisoning (Hawton et al., 2013; Hor and Taylor, 2010; Verrocchio et al., 2016). In the US, suicides by firearms are more common than suicides by these other methods (ASFP, 2017; Boggs et al., 2018; Stone et al., 2018) and are used more often for suicidal behaviors than for homicides each year (Lewiecki and Miller, 2013). Some individuals might purposely choose firearms as suicide means because of the greater lethality (Shenassa et al., 2003) and/or their familiarity with firearms (Anestis et al., 2020). Some studies identified a link between mental disorders, including post-traumatic stress disorder (PTSD) or schizophrenia and increased risk of firearm-related suicide (Desai et al., 2008; Price et al., 2009; Shah et al., 2000; Shields et al., 2007).

However, other studies have not documented such relationships (Boggs et al., 2018; Brent et al., 1991; Callanan and Davis, 2012; Choi et al., 2017a; Choi et al., 2017b; Choi et al., 2018; Kaplan et al., 2012; Kaplan et al., 2009; Stone et al., 2018; Trigylidas et al., 2016). For example, individuals, especially those aged 50+ years, with a mental disorder such as depression or bipolar disorder had lower odds of dying using firearms than other means (Choi et al., 2018). Understanding the role that firearms may play in suicidal behavior among individuals with a diagnosis of a mental disorder may be useful in regulating access to firearms in this population (Boggs et al., 2018).

Previous systematic reviews showed that alcohol abuse, fewer restrictions on firearm control, and direct access to firearms increase the firearm-suicide risk (Anglemyer, 2014; Branas et al., 2016b; Hahn et al., 2005). However, these reviews did not specifically assess the link between mental disorders and the use of firearm in suicidal behaviors (Anglemyer, 2014; Branas et al., 2016b; Hahn et al., 2005). To our knowledge, there is no systematic review addressing this question. Since presence of mental disorders is associated with a greater risk of death by suicide using any means (Balázs, 2006; Bostwick and Pankratz, 2000; Gradus et al., 2010; Tondo et al., 2003), we assessed whether the presence of any mental disorder was
associated with an increased risk of death by suicide specifically using a firearm. Therefore, our primary objectives were to systematically review and synthesize evidence from primary observational studies (i) whether any mental health condition is associated with an increased risk of firearm-related suicide, and (ii) whether the risk of using a firearm, compared with other means is associated with higher levels of suicide in individuals with any mental disorder.

2. Methods

2.1 Protocol and Registration

This systematic review accords with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009), and it is part of a more extensive systematic review registered a priori (PROSPERO, CRD42019117896). See S1 Appendix for the PRISMA checklist.

2.2 Eligibility criteria

This article focuses on exploring whether mental disorders are a precipitating factor for firearm-related suicide. In this systematic review, eligible studies had to be conducted in the US with firearm-related suicide (completed) as the outcome. Suicide is defined as “death caused by self-directed injurious behavior with any intent to die as a result of the behavior” (O’Connor, 2013) and firearm defines as “a lethal barreled weapon of any description from which any shot, bullet or another missile can be discharged” (CPS, 2019). Studies had to include any mental disorder as the exposure with male and/or female decedents of any age. We included any type of observational studies (cross-sectional, case-control, and cohort studies) and grey literature. We excluded editorials, letters, books, book chapters, opinion papers, blogs, case studies, systematic reviews and meta-analyses, and randomized-controlled
trials. We excluded articles in languages other than English. We excluded studies involving suicides within war/military conflicts for two reasons: 1) War and military conflicts usually occur outside the US, and 2) given the mental health screening process before troop deployment (Hyams, 2006), any post-deployment mental disorder is likely to be related to being deployed to a war/military conflict (Russell and Russell, 2019). We also excluded studies including air, pellet, or nail guns as, by definition, they are non-firearm, and are usually unregulated under the Federal firearms law. We did not add a publication date limit to the search.

2.3 Information source

A search strategy was developed with the help of a reference librarian (S.O'D). It was implemented to search the following electronic databases: MEDLINE (Covidence Systematic Review) (48), PsycINFO EBSCOhost, Embase (Covidence Systematic Review), Scopus, Criminal Justice abstract EBSCOhost, Global Health (Covidence Systematic Review), SocIndex, Academic Search Complete, Political Science Complete, Social Policy and Practice, OpenGrey. The initial search was done in December 2018. A second search was completed on the 24th of May 2020. The search strategy is presented in S2 Appendix.

2.4 Study selection

Studies were uploaded to the Covidence software (Covidence Systematic Review, 2014). The selection process was followed by the inclusion and exclusion criteria stated in the initial protocol (S3 Appendix). Title and abstract as well as full-text screening were performed independently by pairs of two reviewers (A. Z., S. B., S. P. H., N. B., D.S.) according to the eligibility criteria. Conflicts were discussed and resolved by two researchers. When consensus could not be reached; a third independent author was consulted.
2.5 Data collection process

Information from the studies was extracted using a customized data extraction form. We collected data on study design, decedents’ information, and demographics (sample size, age, sex), the type of mental disorder (we divided diagnosis into two groups: mood or non-mood disorders), and the method of diagnosing decedents (e.g., interviews with family and friends). We also collected information on the type of firearm and study results (number of cases, percentage, mean, standard deviation, odds ratio (OR), Pearson’s correlation (r), confidence intervals, and p-values).

2.6 Risk of bias in individual studies

We used the critical appraisal tool from the Joanna Briggs Institute (JBI) for cross-sectional studies (Joanna Briggs Institute, 2017b) and case-control studies (Joanna Briggs Institute, 2017a) to assess the risk of bias at the study level. The tools were applied by two authors (A. Z., D. S.).

2.7 Synthesis of results

All analyses were performed using the ‘meta’ and ‘metafor’ packages of the statistical software R (v.3.6.3). Studies did not provide individual decedents data; therefore, aggregate level data were extracted and then transformed onto the log-odds scale using Comprehensive Meta-Analysis software V3 (Borenstein, 2013). The pooled log OR was then estimated and back-transformed to obtain the OR and its corresponding 95% confidence interval (Hahn et al., 2005). The studies were pooled using random-effects meta-analyses with the Hartung-Knapp-Sidik-Jonkman adjustment (IntHout et al., 2014; Langan et al., 2019). To perform the meta-analyses, we included the proportions of the decedents who died by suicide with firearms in each group (i.e., decedents with a diagnosis of any mental disorders vs. decedents...
without a diagnosis of any mental disorder). We also included the proportions of decedents with any mental disorder who died by suicide using a firearm vs. other means. We excluded studies that had not explicitly provided a diagnosis of any mental disorder. Still, we applied an indicator for the presence of any mental disorder, such as decedents being on medications for mental disorders or using mental health services.

We assessed heterogeneity using the χ2 test on Cochrane’s Q-statistic, $I^2$ and its 95% CI, tau, and $\tau^2$ (Borenstein, 2020). A statistically significant Q-statistic and a non-zero $\tau^2$ value indicated non-trivial between-study heterogeneity (Higgins et al., 2003). We also calculated 95% prediction intervals (PI) around the pooled estimate, which provides information about how much the effect sizes vary across different settings (IntHout et al., 2016). The PIs were calculated for meta-analyses with at least 10 studies (Borenstein, 2020). We investigated small-study effects with Egger’s test and by generating funnel plots for meta-analyses with at least ten studies (Lau et al., 2006). We explored the impact that imputing missing studies might have on the pooled estimate by performing Duval and Tweedie’s trim and fill test (Duval and Tweedie, 2000).

The primary meta-analysis included studies comparing decedents with and without a diagnosis of any mental disorder on the risk of dying by suicide using any firearm. To explore heterogeneity, we then preformed two subgroup meta-analysis; (i) comparing studies that included decedents with different mental disorders (bipolar disorders, schizophrenia, post-traumatic stress disorder) to studies that included decedents with depression, and studies comparing men with different mental disorders to men without a diagnosis of any mental disorders vs. studies comparing women with different mental disorders to women without a diagnosis of any mental disorders. We couldn’t complete a meta-regression as covariate data was limited and poorly reported, and such an analysis would not have been adequately powered (Jackson and Turner, 2017).
3. Results

3.1 Study Selection

The searches revealed 10,887 articles. After reviewing the two-stage screening, 22 studies were included in a systematic review, and 14 (64%) of which were included in the meta-analysis (see PRISMA flow chart in Figure 1).

![Flow Diagram of Study Selection](image)

3.2 Study characteristics

From the 22 eligible studies, there were 19 (86%) cross-sectional designs and 3 (14%) case-control primary studies. The study with the biggest sample size had 41,244 decedents (Kalesan et al., 2018a) and the study with the smallest sample contained 50 decedents.
(Weinberger et al., 2000). From all the studies there were three (14%) which did not provide the total sample size (Hemenway and Miller, 2002; Kaplan et al., 2012; Price et al., 2009). The median sample size across studies was 17,254 decedents (interquartile range: 22,792).

The mean age of decedents by a firearm was 40.53 (SD: 18 years). Four (18%) of the studies (Callanan and Davis, 2012; Shields et al., 2007; Simonetti et al., 2020; Weinberger et al., 2000) provided the mean age of all suicide victims including those who used a firearm as well as those who used other methods. Eleven (50%) studies (Choi et al., 2017b; Desai et al., 2008; Hemenway and Miller, 2002; Joe et al., 2007; Kalesan et al., 2018a; Kaplan et al., 2012; Kaplan et al., 2009; Schmutte and Wilkinson, 2020; Schnitzer et al., 2019; Stone et al., 2018; Trigylidas et al., 2016) provided the age range and three (14%) studies (Boggs et al., 2017; Price et al., 2009; Streib et al., 2007) did not provide any information about decedents’ ages. Seventeen (77%) studies (Boggs et al., 2018; Boggs et al., 2017; Choi et al., 2017a; Choi et al., 2017b; Desai et al., 2008; Joe et al., 2007; Kalesan et al., 2018a; Kaplan et al., 2009; Schmutte and Wilkinson, 2020; Schnitzer et al., 2019; Shah et al., 2000; Shields et al., 2007; Simonetti et al., 2020; Stone et al., 2018; Streib et al., 2007; Trigylidas et al., 2016; Weinberger et al., 2000) included both men and women, two (9%) studies included men decedents only (Kaplan et al., 2012; Shah et al., 2000), and one (5%) study included only women decedents (Choi et al., 2018). Only five (23%) studies reported the type of firearm used for the suicide (Callanan and Davis, 2012; Choi et al., 2017a; Shah et al., 2000; Streib et al., 2007; Weinberger et al., 2000). A description of the type of firearm used is shown in Table 3 and Table 4; definitions of each firearm type are included in S4 Appendix.

3.2.1 Exposure

In this systematic review, the term “exposure” refers to the precipitating/risk factor studied throughout this paper, mental disorders. Nine studies (41%) investigated mood disorders such
as major depression, dysthymia, bipolar disorder, and bipolar depression (Boggs et al., 2018; Callanan and Davis, 2012; Choi et al., 2017a; Desai et al., 2008; Hemenway and Miller, 2002; Joe et al., 2007; Kalesan et al., 2018a; Kaplan et al., 2009; Weinberger et al., 2000) (S5 Appendix). Non-mood disorders such as paranoia, drug-induced psychosis, schizophrenia, PTSD, dual diagnosis and dementia were investigated in seven studies (32%) (Boggs et al., 2018; Callanan and Davis, 2012; Choi et al., 2018; Desai et al., 2008; Shah et al., 2000; Shields et al., 2007; Weinberger et al., 2000) (S5 Appendix). There were also seventeen (77%) studies which included non-specific mental disorders, alone or in addition to specific mood and/or non-mood disorders, as an exposure (Boggs et al., 2018; Boggs et al., 2017; Callanan and Davis, 2012; Choi et al., 2017a; Choi et al., 2017b; Choi et al., 2018; Kaplan et al., 2012; Kaplan et al., 2009; Price et al., 2009; Schmutte and Wilkinson, 2020; Schnitzer et al., 2019; Shah et al., 2000; Simonetti et al., 2020; Stone et al., 2018; Streib et al., 2007; Trigylidas et al., 2016; Weinberger et al., 2000).

3.3 Risk of bias within the studies
Three major sources of bias were found within the cross-sectional studies (Table 1). The first one was how the victims’ mental disorder diagnosis were assessed in the studies (Boggs et al., 2017; Callanan and Davis, 2012; Choi et al., 2017a; Choi et al., 2017b; Choi et al., 2018; Desai et al., 2008; Hemenway and Miller, 2002; Joe et al., 2007; Kaplan et al., 2012; Kaplan et al., 2009; Schmutte and Wilkinson, 2020; Schnitzer et al., 2019; Shields et al., 2007; Stone et al., 2018; Streib et al., 2007; Weinberger et al., 2000). There are three commonly established systems for diagnosing mental disorders: International classification of diseases (International Advisory Group for the Revision of and Behavioural, 2011), Diagnostic and Statistical Manual of Mental Disorders (DSM-IV or DSM-V) and the National Institute of Mental Health’s Research Domain Criteria (RDoC) (Clark et al., 2017). Mental disorders in nine studies were not based on any of these diagnostic systems (Callanan and Davis, 2012;
Choi et al., 2017a; Choi et al., 2017b; Choi et al., 2018; Hemenway and Miller, 2002; Joe et al., 2007; Kaplan et al., 2012; Schmutte and Wilkinson, 2020; Streib et al., 2007), and eight of them, including all studies based on the US NVDRS (National Violent Death Reporting System), used the information provided by the decedents’ family/friends (Callanan and Davis, 2012; Choi et al., 2017a; Choi et al., 2017b; Choi et al., 2018; Joe et al., 2007; Kaplan et al., 2012; Schmutte and Wilkinson, 2020; Streib et al., 2007).

There were eight studies that did not report clearly how they measured the exposure (Boggs et al., 2017; Callanan and Davis, 2012; Desai et al., 2008; Kaplan et al., 2009; Schnitzer et al., 2019; Shields et al., 2007; Stone et al., 2018; Weinberger et al., 2000). Studies also did not identify the confounding factors (i.e., baseline characteristics, prognostic factors, or concomitant exposures). They also did not explain the strategies applied to deal with confounders (Boggs et al., 2017; Price et al., 2009; Shields et al., 2007; Weinberger et al., 2000). There were six studies that did not define the inclusion criteria with adequate detail (Price et al., 2009; Shields et al., 2007; Simonetti et al., 2020; Stone et al., 2018; Streib et al., 2007; Weinberger et al., 2000). Two of the three case-control studies (Table 2) measured the exposure based on the information provided by family members (Boggs et al., 2018; Shah et al., 2000), and one did not provide enough information on how the exposure was assessed (Kalesan et al., 2018a).
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<th>Were the study subjects and the setting described in detail?</th>
<th>Was the exposure measured in a valid and reliable way?</th>
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<th>Were confounding factors identified?</th>
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✓: question’s answer is yes
X: question’s answer is no
N/A: not applicable
3.5 Data synthesis

**Comparison of mental disorders vs non-mental disorders on suicide by firearm**

In 14 studies (100,299 decedents) involving 18 comparisons (Figure 2), decedents that had a diagnosis of a mental disorder were significantly associated with lower odds of dying by suicide using a firearm (OR: 0.50, 95% CI: 0.36 to 0.69; 95% PI: 0.12 to 1.99, \(I^2 = 100\%\) (95% CI: 87 to 100)). Studies in this meta-analysis were seen to have varied effect sizes with estimate of small between-study variance (\(\tau^2 = 0.41; \chi^2(21) = 3.998; p < .0001\)). Sensitivity analysis removing the two case-control studies (Boggs et al., 2017; Kalesan et al., 2018a) did not alter the pooled effect (OR: 0.49, 0.34 to 0.70; [PI: 0.11, 2.10], \(I^2 = 100\%\) (84 to 100)).
The subgroup meta-analysis comparing studies including decedents with any mental disorder to studies including decedents with a diagnosis of depression only is presented in Figure 3.

We included eleven studies (involving 14 comparisons, 100,299 decedents), ten of them cross-sectional and one case-control study (Kalesan et al., 2018a). The information extracted from the case-control study is only from one of the groups (controls), which included decedents who died by firearm suicide. This way, we are using the data as if the study would be a cross-sectional study. In this subgroup analysis, there were significantly lower odds for suicide with a firearm in decedents with a diagnosis of any mental disorder compared with decedents without a diagnosis of any mental disorder (OR: 0.48, 95% CI: 0.32 to 0.72; $I^2 =100\%$). In the five studies (7 comparisons) that included decedents with diagnosis of depression, those with a diagnosis of depression showed a statistically significant decrease in

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</tr>
<tr>
<td>Chol 2017b (M)</td>
<td>-0.43</td>
<td>0.02</td>
<td>0.65</td>
<td>0.65</td>
<td>[0.62; 0.68]</td>
<td>6.0%</td>
</tr>
<tr>
<td>Chol 2017b (F)</td>
<td>-0.53</td>
<td>0.05</td>
<td>0.59</td>
<td>0.59</td>
<td>[0.54; 0.65]</td>
<td>6.0%</td>
</tr>
<tr>
<td>Chol 2017a</td>
<td>-2.22</td>
<td>0.06</td>
<td>1.11</td>
<td>1.11</td>
<td>[0.10; 1.12]</td>
<td>5.9%</td>
</tr>
<tr>
<td>Chol 2018</td>
<td>-0.17</td>
<td>0.04</td>
<td>0.85</td>
<td>0.85</td>
<td>[0.78; 0.92]</td>
<td>6.0%</td>
</tr>
<tr>
<td>Desai 2008</td>
<td>-1.00</td>
<td>0.14</td>
<td>0.37</td>
<td>0.37</td>
<td>[0.28; 0.48]</td>
<td>5.7%</td>
</tr>
<tr>
<td>Kalesan 2018</td>
<td>-0.94</td>
<td>0.01</td>
<td>0.39</td>
<td>0.39</td>
<td>[0.38; 0.40]</td>
<td>6.0%</td>
</tr>
<tr>
<td>Kaplan 2009 (M)</td>
<td>-1.80</td>
<td>0.03</td>
<td>0.17</td>
<td>0.17</td>
<td>[0.16; 0.18]</td>
<td>6.0%</td>
</tr>
<tr>
<td>Kaplan 2009 (F)</td>
<td>-0.31</td>
<td>0.07</td>
<td>0.74</td>
<td>0.74</td>
<td>[0.64; 0.84]</td>
<td>5.9%</td>
</tr>
<tr>
<td>Streib 2007</td>
<td>-1.79</td>
<td>0.22</td>
<td>0.17</td>
<td>0.17</td>
<td>[0.11; 0.26]</td>
<td>5.4%</td>
</tr>
<tr>
<td>Trigyidas 2016</td>
<td>-0.22</td>
<td>0.37</td>
<td>0.80</td>
<td>0.80</td>
<td>[0.39; 1.65]</td>
<td>4.5%</td>
</tr>
<tr>
<td>Schmutte 2020 (M)</td>
<td>-0.62</td>
<td>0.03</td>
<td>0.54</td>
<td>0.54</td>
<td>[0.51; 0.57]</td>
<td>6.0%</td>
</tr>
<tr>
<td>Schmutte 2020 (F)</td>
<td>-0.63</td>
<td>0.06</td>
<td>0.53</td>
<td>0.53</td>
<td>[0.47; 0.60]</td>
<td>5.9%</td>
</tr>
<tr>
<td>Shields 2007</td>
<td>-0.14</td>
<td>0.53</td>
<td>0.87</td>
<td>0.87</td>
<td>[0.31; 2.44]</td>
<td>3.6%</td>
</tr>
<tr>
<td>Stone 2018</td>
<td>-0.93</td>
<td>0.03</td>
<td>0.39</td>
<td>0.39</td>
<td>[0.37; 0.42]</td>
<td>6.0%</td>
</tr>
<tr>
<td>Simonetti 2020</td>
<td>-0.12</td>
<td>0.02</td>
<td>0.89</td>
<td>0.89</td>
<td>[0.85; 0.92]</td>
<td>6.0%</td>
</tr>
</tbody>
</table>

Figure 2. Forest Plot Meta-Analysis comparing cross-sectional studies and one case-control study that included decedents without a diagnosis of mental disorders to decedents with a diagnosis of any mental disorders on the odds of dying by suicide by firearm. Error Bars represent 95% CI. (M): Men population; (F): Women population. TE: refers to the log transformed OR. seTE: refers to the log-transformed standard error OR.
odds for death by suicide with a firearm than those without a diagnosis of depression (OR: 0.52, 95% CI: 0.38 to 0.70, $I^2 = 100\%$ (95 to 100)).

The subgroup analysis with the five studies comparing men to women with, as opposed to without, a diagnosis of any mental disorder on the odds of dying by suicide with a firearm is provided in Figure 4. The results showed that studies including men with a diagnosis of any mental disorder did not have significantly lower odds of dying by suicide with a firearm than...
men without a diagnosis of any mental disorder (OR: 0.48, 95% CI: 0.20 to 1.12, $I^2 = 100\%$).

Women with a diagnosis of any mental disorder had a significantly lower odds of dying by suicide with a firearm than women without a diagnosis of any mental disorder (OR: 0.62, 95% CI: 0.51 to 0.75, $I^2=71\%$ (26 to 89)). The weighted average pooled estimate of the subgroup of studies including men decedents (OR: 0.48) was not significantly different ($p = 0.5448$) than the weighted average pooled estimate of the subgroup of studies including women decedents (OR: 0.62).

![Forest Plot](image)

*Figure 4. Forest Plot Subgroup Meta-Analysis comparing studies including men vs. women with or without a diagnosis of mental disorder on the odds of dying by suicide by firearm suicide. TE: refers to the log transformed OR. seTE: refers to the log-transformed standard error OR.*

**Comparison of suicide death due to firearms access against those with no access to firearms in decedents with a mental disorder**

Decedents in six studies with a diagnosis of any mental disorder had on average significantly lower odds of dying by suicide by using a firearm than any other method (OR: 0.52, 95% CI:
0.30 to 0.91; [PI: 0.12 to 2.69]; \( I^2 = 99\% \) (98.7 to 99.2), Figure 5). Studies in this meta-analysis did not share a common effect size and the true effect likely varied (\( \tau^2 = 0.36; \chi^2 (7) = 1108, p < 0.001 \)).

Figure 5. Forest Plot Meta-Analysis of studies comparing the use of a firearm vs. other means in decedents with a diagnosis of any mental disorder. M: Men population; F: Women population. TE: refers to the log transformed OR. seTE: refers to the log-transformed standard error OR.

Figure 6 shows the subgroup analysis comparing studies including decedents with any mental disorders to studies including decedents with a diagnosis of depression only. In the four studies that included decedents with any mental disorder, decedents had on average a lower, but non-significant, odds of dying by suicide with a firearm than using any other method (OR: 0.45, 95% CI: 0.20 to 1.01; \( I^2 = 100\% \)). In the three studies, including decedents with depression, decedents showed no significant change of suicide with a firearm or when using another weapon (OR: 0.78, 95 CI: 0.08 to 7.96, \( I^2 = 79\% \) (37 to 92%)). The weighted average pooled estimate of the subgroup of studies including decedents with any mental disorders (OR: 0.45) was not significantly different \( (p = 0.1092) \) than the weighted average pooled estimate of the subgroup of studies including decedents with depression (OR: 0.78).
In Figure 7, the subgroup analysis comparing men with any mental disorders to women with any mental disorders, showed no significant differences in the odds of dying by suicide by firearm vs. any other method among men (OR: 0.67; 95% CI: 0.43 to 1.04; $I^2 = 49\%$ (12 to 89)). However, there was a significant increase in odds of suicide by firearm among women (OR: 0.59; 95% CI: 0.54 to 0.65; $I^2 = 0\%$). The weighted average pooled estimate of the subgroup of studies including men decedents with any mental disorders (OR: 0.67) was not significantly different ($p = 0.0011$) than the weighted average pooled estimate of the subgroup of studies including decedents with depression (OR: 0.59).
Small-Study Effects

Initial assessment for small-study effects was done using Egger’s statistic which showed no significance ($p = 0.829$). We also assessed small-study effects by visual inspection of the funnel plot in Figure 8 using trim and fill method. The funnel plot revealed slight asymmetry, and the test statistic showed small-study effect bias ($p < 0.0001$).

3.4 Narrative results of individual studies

The primary outcome of this review was death by suicide with a firearm (Table 3 and 4; S6 S7 Appendix). There were eleven studies examining suicide by firearm as their only outcome (Boggs et al., 2017; Choi et al., 2017a; Desai et al., 2008; Hemenway and Miller, 2002; Joe et al., 2007; Kalesan et al., 2018a; Schnitzer et al., 2019; Shah et al., 2000; Shields et al., 2007; Streib et al., 2007; Weinberger et al., 2000), eleven studies investigated firearm suicides, but they also included other suicide methods (Boggs et al., 2018; Callanan and Davis, 2012; Choi et al., 2017b; Choi et al., 2018; Kaplan et al., 2012; Kaplan et al., 2009; Schmutte and Wilkinson, 2020; Shields et al., 2007; Simonetti et al., 2020; Stone et al., 2018; Trigylidas et
such as hanging/suffocation and drug poisoning (Callanan and Davis, 2012; Choi et al., 2018; Stone et al., 2018) and blunt injury, jumping, laceration or/and drowning (these papers did not specify where the injuries occurred or where the decedents were jumping from/into) (Choi et al., 2017b; Kaplan et al., 2012; Kaplan et al., 2009; Schmutte and Wilkinson, 2020; Shields et al., 2007; Simonetti et al., 2020; Trigylidas et al., 2016). One study did not specify what the other suicide methods decedents used other than firearms (Boggs et al., 2018).

![Figure 8. Trim and Fill Funnel Plot](image-url)
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size (N); Age (mean); Sex (n, %)</th>
<th>Mood-based disorder</th>
<th>Non-mood-based disorder/ suicide attempt</th>
<th>Method of diagnosis/data collected from</th>
<th>Type of firearm (N or %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boggs 2017</td>
<td>N=1,298, Overall*=2,674; Age=N/A; Overall*Men=75.5%, Women=24.5%</td>
<td>Mental disorder</td>
<td>Suicide attempt</td>
<td>Medical records and claims information</td>
<td>N/A</td>
</tr>
<tr>
<td>Callanan 2012</td>
<td>N=303, Overall*=621; Age*=45 (no SD); Men*=249 (51.8%), Women*=54 (38.3%)</td>
<td>Depression, on psychiatric medication</td>
<td>N/A</td>
<td>Information obtained from interviews with law enforcement, neighbors, friends, and health care providers</td>
<td>Long guns: Male=22.4%, Female=11.3%; Handguns: Male=77.6%, Female=88.7%</td>
</tr>
<tr>
<td>Choi 2018</td>
<td>N=4,190; Overall*N=12,401; Age=61.33 (0.15); Women=100%</td>
<td>Mental disorder - depression, Bipolar disorder</td>
<td>Schizophrenia, PTSD</td>
<td>National Violent Death Reporting System</td>
<td>N/A</td>
</tr>
<tr>
<td>Choi 2017a</td>
<td>Men: N 50–64 years=13,312; Overall*=22,460; Age=56.10 (0.03); N 65+</td>
<td>Mental disorder</td>
<td>Suicide attempt</td>
<td>National Violent Death Reporting System</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Table 3. Cross-sectional Studies Investigating the Relationship Between Mental Disorders and the Risk of Suicide by Firearm

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size (N); Age (mean); Sex (n, %)</th>
<th>Mood-base disorder</th>
<th>Non-mood-based disorder/suicide attempt</th>
<th>Method of diagnosis/data collected from</th>
<th>Type of firearm (N or %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choi 2017b</td>
<td>N=3,116, Overall*=7,489; Age=17.62 (0.04)*; Men=2,765 (88.73%), Women=351 (11.27%)</td>
<td>Mental disorder, depression</td>
<td>Suicide attempt</td>
<td>National Violent Death Reporting System</td>
<td>Handgun=54.72%; Rifle=18.7%; Shotgun=17.72%; Unknown=8.72%</td>
</tr>
<tr>
<td>Desai 2008</td>
<td>N=440, Overall*=1,057; Age range 18-29=23; 30-39=56; 40-49=193; 50-59=83; 60-69=47; 70+=38; Men=432 (42.44%), Women=8 (20.51%)</td>
<td>Bipolar depression, major depression</td>
<td>Schizophrenia, PTSD, Dual diagnosis</td>
<td>The Patient Treatment File: Veterans Affairs administrative database</td>
<td>N/A</td>
</tr>
<tr>
<td>Hemenway 2002</td>
<td>N=N/A; Age=33.4 (no SD); Depression</td>
<td>N/A</td>
<td>Self-reported National</td>
<td>N/A</td>
<td>No significant correlation between firearm</td>
</tr>
</tbody>
</table>

Relative to decedents without a mental disorder.

The odds of using a firearm to die by suicide were significantly lower in decedents with a mental disorder relatively to decedents without a mental disorder.

The odds of using a firearm vs. other methods to die by suicide were higher in men decedents with PTSD relatively to men decedents without PTSD. The odds of using a firearm to die by suicide were significantly lower in decedents with major depression relatively to decedents without major depression.
Table 3. Cross-sectional Studies Investigating the Relationship Between Mental Disorders and the Risk of Suicide by Firearm

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size (N); Age (mean); Sex (n, %)</th>
<th>Mood-based disorder</th>
<th>Non-mood-based disorder/suicide attempt</th>
<th>Method of diagnosis/data collected from</th>
<th>Type of firearm (N or %)</th>
<th>Interpretation of results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joe, 2007</td>
<td>N=977, Overall*=1616; Age range 18-34=30.6%; 35-64=42.4%; 65+=26.9%; Men=86.9%, Women=13.1%</td>
<td>Use depression medicine</td>
<td>N/A</td>
<td>Next-of-kin interview</td>
<td>N/A</td>
<td>The odds of using a firearm vs. other methods to die by suicide were significantly lower in decedents using medications for depression relative to decedents who did not use medications for depression.</td>
</tr>
<tr>
<td>Kaplan, 2012</td>
<td>N=N/A, Overall*=4,338; Age=65+; Men=100%</td>
<td>Mental disorder, depression</td>
<td>Suicide attempt</td>
<td>Interview family and friends</td>
<td>N/A</td>
<td>The odds of using a firearm vs. other methods to die by suicide were significantly lower in men decedents with a mental disorder relative to men decedents without a mental disorder.</td>
</tr>
<tr>
<td>Kaplan, 2009</td>
<td>N=13,294, Overall*=25,491; Men age range:18–34=2,899; 35–44=2,054; 45–64=3,995; 65+=2,605; Women age range:18–34=382; 35–44=390; 45–64=758; 65+=210; Men=11,554, Women=1,740</td>
<td>Mental disorder, depression</td>
<td>Suicide attempt</td>
<td>Proxy (not details provided by authors) and DSM-IV</td>
<td>N/A</td>
<td>The odds of using a firearm vs. other methods to die by suicide were significantly lower in decedents with a mental disorder relative to decedents without a mental disorder. The odds of using a firearm vs. other methods to die by suicide were significantly higher in women decedents with depression relative to women decedents</td>
</tr>
<tr>
<td>Study</td>
<td>Sample size (N); Age (mean); Sex (n, %)</td>
<td>Mood-base disorder</td>
<td>Non-mood-based disorder/suicide attempt</td>
<td>Method of diagnosis/data collected from</td>
<td>Type of firearm (N or %)</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------</td>
<td>--------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>-------------------------</td>
<td></td>
</tr>
<tr>
<td>Price 2009</td>
<td>N/A</td>
<td>Mental disorder</td>
<td>N/A</td>
<td>DSM-IV (details not provided by authors)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Suicidal by firearm was positively associated with the prevalence of mental disorders.</td>
<td></td>
</tr>
<tr>
<td>Shields 2007</td>
<td>N=14, Overall*=2,864; Age=42.0 (11-96); Men=8, Women=6</td>
<td>N/A</td>
<td>Schizophrenia</td>
<td>Documented history of schizophrenia reported by the coroner</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The most common method of suicide among decedents with schizophrenia was firearm.</td>
<td></td>
</tr>
<tr>
<td>Schmutte 2020</td>
<td>N=19,158, Overall*=26,884; Age*65–69=7,893; 70–74=6,055; 75–79=4,917; 80–84=4,091; ≥85=3,928; Men=17,449, Women=1,684</td>
<td>Mental disorder</td>
<td>N/A</td>
<td>National Violent Death Reporting System</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The odds of using a firearm to die by suicide were significantly lower in decedents with a mental disorder relatively to decedents without a mental disorder.</td>
<td></td>
</tr>
<tr>
<td>Schnitzer 2019</td>
<td>N=1,388; Age range=10-14=330;15-18=1,058; Men=1,175; Women=210 (3 cases gender missing**);</td>
<td>Mental health service, on medication</td>
<td>N/A</td>
<td>Not specified. Information taken from “Fatality Review-Case Reporting System”</td>
<td>Handgun=827; Other guns=481; Missing=80</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The odds of using a firearm vs. other methods to die by suicide were significantly lower in decedents using medications for a mental health issue relative to decedents who did not use medications for a mental health issue.</td>
<td></td>
</tr>
<tr>
<td>Simonetti 2020</td>
<td>N=19,111, Overall*=27,741; Age*=62 (16); Men*= 26,883, Women*=858</td>
<td>Mental disorder</td>
<td>N/A</td>
<td>ICD-9 codes (codes were not specified by the authors)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The odds of using a firearm to die by suicide were significantly lower in decedents with a mental disorder relatively to decedents without a mental disorder.</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Cross-sectional Studies Investigating the Relationship Between Mental Disorders and the Risk of Suicide by Firearm.
Table 3. Cross-sectional Studies Investigating the Relationship Between Mental Disorders and the Risk of Suicide by Firearm

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size (N); Age (mean); Sex (n, %)</th>
<th>Mood-base disorder</th>
<th>Non-mood-based disorder/suicide attempt</th>
<th>Method of diagnosis/data collected from</th>
<th>Type of firearm (N or %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone 2018</td>
<td>N = 9,909 (48.5%); Overall*=20.44 6; Age*=46.72 (18.26)(\bar{x}); Men*=15,702 (76.8%), Women*=4,744 (23.2)</td>
<td>Mental disorder</td>
<td>N/A</td>
<td>DSM-V (details not provided by authors)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The odds of using a firearm vs. other methods to die by suicide were significantly lower in decedents with a mental disorder relative to decedents without a mental disorder.</td>
</tr>
<tr>
<td>Streib 2007</td>
<td>N=200; Age=N/A; Men=168, Women=32</td>
<td>Mental disorder</td>
<td>Suicide attempt</td>
<td>Interview family, friends, neighbors, or physician</td>
<td>Handgun=7 2%; Shotgun=1 8%; Rifle=6%; Unknown=4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Among both sexes, the odds of using a firearm to suicide were significantly lower among those with a mental disorder.</td>
</tr>
<tr>
<td>Trigylidas 2016</td>
<td>N=1,020, Overall*=2850 Age*=15.6 (no SD); Men*=2099 (73.6%), Women*=751 (26.4%)</td>
<td>Mental disorder</td>
<td>N/A</td>
<td>Child death Review case Reporting system</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No significant difference in suicides by firearm between decedents with a mental disorder and decedents without a mental disorder.</td>
</tr>
<tr>
<td>Weinberger 2000</td>
<td>N = 30; Age=35 (8-78); Men=47 (94%), Women=3 (6%)</td>
<td>Mental disorder , depression, bipolar disorder</td>
<td>Depression and paranoia, drug-induced psychosis, drug abuse and depression</td>
<td>Medical report</td>
<td>Revolver=2 8; Semi-automatic=1 5; Rifle=5; Home-made device=1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Among decedents who died by suicide by firearm, 42% of decedents had a mental disorder.</td>
</tr>
</tbody>
</table>

DSM-IV/V: Diagnostic and Statistical Manual of Mental Disorders, edition 4/5; ICD-9 codes: the official system of assigning codes to diagnoses and procedures associated with hospital utilization in the United States; MISA: mental illness and substance abuse; non-MISA: no mental illness nor substance abuse; N: number; PTSD: post-traumatic syndrome disorder \(\bar{x}\): Standard deviation (SD) 
\#: Standard error 
*: Include suicides by firearm and other means 
** There were three suicide cases collected in this paper where the gender was not specified 
N/A: not available
Table 4. Case-control Studies Investigating the Relationship Between Mental Disorders and the Risk of Suicide by Firearm

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size (N); Age (mean); Sex (n, %)</th>
<th>Mood-base disorder</th>
<th>Non-mood-based disorder/suicide attempt</th>
<th>Method of diagnosis/data collected from</th>
<th>Type of firearm (N or %)</th>
<th>Interpretation of results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boggs 2018</td>
<td>Cases: N=1,298, Control N=129,800; Cases Age=53 (19.1), Control Age=39.5 (22)</td>
<td>Bipolar disorder, depression</td>
<td>Schizophrenia, anxiety disorder, dementia, other psychosis</td>
<td>ICD-9 codes</td>
<td>N/A</td>
<td>Compared with the control group, the odds of having a mental disorder were significantly larger for the other-modes group compared with the firearm group.</td>
</tr>
<tr>
<td>Kalesan 2018</td>
<td>N=41,244; Age range less/equal 30=8,413 (20.4%); &gt;30=32,781 (79.5%); Unknown=50 (0.1); Men=35,633 (86.4), Women=35,633 (86.4), Unknown=5 (0.1)</td>
<td>Mental disorder, depression</td>
<td>Disclosed intent of suicide</td>
<td>National Violent Death Reporting System</td>
<td>N/A</td>
<td>The odds of using a firearm vs. other methods to die by suicide were significantly lower in decedents with depression/mental disorder relative to decedents without depression/mental disorder.</td>
</tr>
<tr>
<td>Shah 2000</td>
<td>Total Cases N=54, Cases died by suicide with firearm=36, Control=36; Age=15 (9-17); Men=27 (75%), Women=9 (25%)</td>
<td>Mental disorder</td>
<td>Suicide attempt</td>
<td>Questionnaires to parent or guardian</td>
<td>Cases: Handgun=42%; Rifle=46%; Shotgun=4%; Unknown=8%</td>
<td>Comparing with the control, the odds of using a firearm vs. other methods to die by suicide were higher in decedents who ever been treated by mental health professionals or</td>
</tr>
</tbody>
</table>
4. Discussion

4.1 Summary of evidence

We explored whether mental health is associated with suicide using a firearm. There are discrepant research findings. Some evidence shows that individuals with mental disorders have higher odds of dying by suicide using a firearm than other means (Desai et al., 2008; Price et al., 2009; Shah et al., 2000; Shields et al., 2007). But there is also evidence linking mental disorders with a lower risk of dying by suicide using a firearm than using other means (Boggs et al., 2018; Callanan and Davis, 2012; Choi et al., 2017a; Choi et al., 2017b; Choi et al., 2018; Kaplan et al., 2012; Kaplan et al., 2009). To our knowledge, no systematic review has robustly synthesized the available evidence for the link between mental health and suicide by firearm. Because of discrepancies in the literature and the lack of a systematic review in this field, we aimed to synthesize the available evidence in a systematic review.

4.2 Mental disorders vs. no-mental disorders on suicide by firearm
Not having a diagnosis of a mental disorder (e.g., depression, bipolar disorder, schizophrenia, and PTSD) was, on average, associated a 55% higher likelihood of using a firearm when dying by suicide than having a mental disorder (Figure 2). The 95% PI showed the magnitude of this relationship varied across different settings. In some settings, this relationship was absent, while in others, it ran in the opposite direction (Riley et al., 2011). This wide dispersion of effect sizes is likely to reflect substantial heterogeneity across the studies within this meta-analysis (Figure 2). Several factors may explain this variation in effect sizes, including the type of mental disorder, age, or the sex of the decedents (Boggs et al., 2018; Callanan and Davis, 2012; Choi et al., 2018). For example, there is evidence suggesting that PTSD is linked with a higher risk of firearm suicide compared with other mental disorders such as depression or schizophrenia (Desai et al., 2008) and men are more likely to use a firearm in suicide (Callanan and Davis, 2012) and, therefore, men also account for a higher proportion of firearm suicides than women (Fowler et al., 2015).

To explore the observed wide dispersion of effect sizes (Figure 2), we performed a subgroup analysis by comparing studies that had recruited decedents with any mental disorder to studies that had recruited decedents with depression (Figure 3). Results showed similar results as the main meta-analysis (Figure 2), with decedents who had depression having lower odds of dying by suicide using a firearm than decedents who did not have depression (Figure 3). It is also possible that differences in the type of mental disorder might explain differences in the magnitude of effect sizes across different settings (Too et al., 2019). However, since studies did not always report the type of mental disorder, we could not assess whether other disorders such as PTSD or schizophrenia contributed to the observed heterogeneity (Higgins and Green, 2008). From these meta-analyses (Figures 2 and 3), we excluded two studies that did not report
a mental disorder diagnosis among decedents but instead reported that decedents were under psychiatric medication (Joe et al., 2007; Schnitzer et al., 2019).

We also performed a subgroup analysis by comparing studies that included only men to studies that included only women on suicide by firearm. There was no between-subgroup difference between the odds for men and women, suggesting no gender difference in the odds of firearm suicides. However, women without a mental disorder diagnosis had higher odds of dying by suicide using a firearm than women diagnosed with any mental disorder (Figure 4). This unexpected finding is not consistent with past literature suggesting that women usually select less lethal methods than men in suicide (Denning et al., 2000) but may use self-poisoning for suicidal acts (Callanan and Davis, 2012). Accessibility of suicide methods can impact suicide occurrence (Elnour and Harrison, 2008). The restriction in the availability of particular methods has been related to decreased method-specific suicide rates (Elnour and Harrison, 2008). Therefore, women with a mental disorder may have more restrictions accessing firearms than women without a mental disorder (Sen and Panjamapirom, 2012).

Of note, the number of studies in most subgroups was small, rendering the analysis likely underpowered (Jackson and Turner, 2017) and increasing the probability of a type I error (Christley, 2010). For example, in the subgroup analysis comparing men and women with and without a mental disorder, only five studies included. Give that subgroup analyses are only observational (Thompson and Higgins, 2002), we cannot assume that this relationship existed only among women. It is possible that certain factors (e.g., level of education (Shojaei et al., 2014)) were present in the subgroup of women, but absent in the subgroup of men, that increased the risk of dying by firearm suicide in those without a mental disorder. In addition, subgroup analyses are by default observational and cannot establish cause and effect (Thompson and Higgins, 2002).
Studies investigating the relationship between previous suicide attempts and suicide by firearm found those who used a firearm in suicide were less likely to have had a prior suicide attempt (Boggs et al., 2017; Callanan and Davis, 2012; Choi et al., 2017a; Choi et al., 2017b; Kaplan et al., 2009). It may be that individuals who have attempted to die by suicide and who are not determined about ending their lives avoid using highly lethal methods, while individuals with greater intent on dying by suicide use more lethal methods such as firearms (Kaplan et al., 2009). A study concluded that those who had a prior suicide attempt were associated with a lower probability of firearm access (Ilgen et al., 2008) which may be because if a firearm had been available during the first attempt, these individuals might have died at that time. Other factors underlying the demographics of the included decedents may also explain the variation in effect sizes (Figure 2). For example, although suicide is the third leading cause of death in young adults between 15-24 years old (Cash and Bridge, 2009), the firearm-suicide rate is higher in adults over 50 years (Kalesan et al., 2018b). However, we could not explore this as the data on age was limited and poorly reported in most studies.

Despite the evidence that most individuals were seeking healthcare services in the year before suicide death, approximately half of these individuals did not have a psychiatric condition (Ahmedani et al., 2014). However, approximately 31% of the US population is diagnosed with a mental illness every year, but only a third of these individuals are treated (Kessler et al., 2005; Thornicroft, 2008). The high cost and insufficient insurance coverage, long waits as well as lack of awareness (not knowing where to go or being unsure where to find appropriate resources online), and social stigma about having a mental health condition may discourage a person from accessing mental health services (Wood et al., 2018). These barriers might contribute to categorizing decedents between those with an undiagnosed mental health condition as not having a mental
disorder in primary research. These factors can, in turn, contribute to heterogeneity in meta-analyses (Higgins and Green, 2008).

### 4.3 Suicide by firearm vs. other means

We pooled studies investigating decedents diagnosed with mental health conditions who died by suicide with a firearm compared with those who died by suicide with other means (e.g., hanging/suffocation, drug poisoning, blunt injury, or drowning) (Figure 5). Results showed that suicide victims with mental health conditions had lower odds of dying by suicide with a firearm than other means. A possible explanation for our results might be that people with mental disorders have less access or more obstacles to obtain firearms (Kaplan et al., 2009). Some states in the US, such as Indiana or Connecticut (Kivisto, 2018), which have background checks for both criminal history and mental illness, tend to have lower firearm suicide rates than states which only implement criminal history checks (Sen and Panjamapirom, 2012; Sumner et al., 2008). Other studies showed that individuals with mental disorders were no more or less likely to have access to firearms than others without mental disorders (Ilgen et al., 2008; Swanson et al., 2015).

Results from one meta-analysis (Figure 6) suggested that the odds of dying by suicide are similar regardless of the suicide method in decedents with depression. Likewise, some primary studies found that, especially among older decedents those who died by firearms were less likely than the other decedents, to have been identified as having depression (Choi et al., 2017a; Choi et al., 2018). A study found that among women, having depression was associated with higher odds of using a firearm in suicide than other means (Kaplan et al., 2009). The absence of differentiation by sex in our meta-analysis might explain the lack of between-group difference in this meta-analysis.
Whether sex plays a role in dying by suicide remains an issue of contention (Callanan and Davis, 2012). For example, one study found that firearms were the most common method of suicide among both sexes (Callanan and Davis, 2012). Another concluded that a firearm was the first method of choice by men but the second selected by women (Kposowa and McElvain, 2006). However, a recent meta-analysis showed mixed results on the relationship between sex and the selection of suicide methods (Salk et al., 2017).

### 4.4 Small-study effects

Small-study effects occur when smaller studies sometimes show different, often larger, treatment effects than large studies (Sterne and Egger, 2001) and may threaten the validity of the results (Sutton et al., 2000). We conducted Egger’s test to explore whether the small-study effect was present in any of our meta-analyses (Lin and Chu, 2018). Egger’s test was not statistically significant in every meta-analysis, suggesting that small-study effects were not present. One source of small study effects is publication bias, which is prevalent in psychology, social sciences (Ferguson and Heene, 2012; Franco et al., 2014) and, medicine (Onishi and Furukawa, 2014; van Aert et al., 2019). Consequently, there is reason to suggest that it is also likely to be present in the field of criminology (Rothstein, 2008). Given that publication bias was present in our meta-analyses, we stress the need to interpret these results with caution.

### 4.5 Limitations

This study had several limitations including within the included studies. Most studies did not describe or employ a suitable method to assess the mental disorders which limit the studies’ external validity (Carlson and Morrison, 2009), and 77% of these studies did not specify the type of mental health diagnosis. Further, decedents with different mental disorders were combined in the same analytic sample and which is a source of
uncertainty because it is unclear whether the type of mental disorder, e.g., PTSD or bipolar disorder, may be differentially related to dying by suicide using a firearm. Also, a few studies used the NVDRS to obtain information on decedents’ mental health (Choi et al., 2017a; Choi et al., 2017b; Kalesan et al., 2018a; Schmutte and Wilkinson, 2020). While this database is considered one of the most comprehensive sources of data on suicide in the US, the findings may not be generalizable to all US suicide decedents (Choi et al., 2017a; Choi et al., 2017b; Schmutte and Wilkinson, 2020) because during the period the studies were performed half of the states in the US did not provide data to the NVDRS.

The NVDRS and other studies collected decedents’ mental health diagnoses from families during interviews (Callanan and Davis, 2012; Joe et al., 2007; Kaplan et al., 2012; Kaplan et al., 2009; Shah et al., 2000; Streib et al., 2007). This method is confounded by recall bias (Grimes and Schulz, 2002; RAND, 2021). Some of the included cross-sectional studies also did not control for potential confounding factors, such as age, sex, or geographic location, which may limit the internal validity of the included studies (Boggs et al., 2017; Price et al., 2009; Shields et al., 2007; Weinberger et al., 2000). These factors are important because using a firearm as a suicide method may vary by age and geographic region in the US (Choi et al., 2017a; Choi et al., 2017b; Choi et al., 2018; Hemenway and Miller, 2002; Kaplan et al., 2012; Kaplan et al., 2009). Studies did not provide the typology of the firearm that was used by the decedents, which may be relevant in improving firearm regulations and develop programs and policies designed to reduce the accessibility of firearms (Grossman et al., 2005) as it would provide information about which firearms are used to inflict the greatest harm to oneself or others.
There are also limitations in this systematic review that need to be considered. Firstly, the number of studies included in each meta-analysis is relatively small; standard random-effects meta-analysis methods perform poorly when applied to few studies (Seide et al., 2019). Therefore, whether the estimates are close to the true value is questionable. Second, we included observational studies, which cannot establish cause and effect (Boyko, 2013). The included observational studies may not have accounted for unknown variables that affect the result as they do not have the advantage of random assignment (Boyko, 2013) and may overestimate the effect size due to participants’ heterogeneity or they may contain biases that are intrinsic to their design (Muriel et al., 2012).

It is also worth mentioning one of the main challenges in this field: the absence of standard psychiatric biomarkers in clinical practice (García-Gutiérrez et al., 2020) such as suicidality risk (Costanza et al., 2014). Psychological autopsies are used to determine the cause of suicide and provide more precise insights into the process of suicide (Isometsä, 2001). This method has shown that around 90% of suicide decedents had a mental disorder prior to suicide (Cavanagh et al., 2003), but several authors have criticized this method by arguing that there is insufficient evidence on the reliability and validity of this method (Hjelmeland and Knizek, 2017; Pouliot and De Leo, 2006) and that the available evidence to support the validity of psychological autopsies is weak (Hjelmeland and Knizek, 2017). As such, standardization of psychological autopsies is recommended (Pouliot and De Leo, 2006).

4.6 Strengths

To our knowledge, this is the first systematic review exploring the relationship between mental disorders and suicides by firearm in which studies were pooled together in a
robust meta-analysis. We also were able to conduct subgroup analyses on types of mental disorders that add new information to the primary studies, allowing us to explore the heterogeneity of the results. This review should help to develop policy and guidelines in the US further.

4.7 Suggestions for future research

Following the results from our risk of bias assessment (Table 1 and Table 2), future studies investigating the link between any mental disorder and risk of dying by suicide using a firearm should consider applying reliable and standard diagnostic methods to gather the information (e.g., ICD-10 or DSM-V) for diagnosing decedents’ mental disorders and specify the type of mental disorder they are examining. Future research should also consider collecting information on age (provide mean age and related standard deviation, not just the age range), sex, geographical region, ethnicity, and substance misuse, all of which have been linked to suicide by firearm (Balis and Postolache, 2008; Branas et al., 2016a; Callanan and Davis, 2012; Kaplan and Geling, 1999) to comprehensively describe decedents’ demographics. This information will be useful for exploring which demographic factor may be responsible for explaining possible presence of heterogeneity in future meta-analyses (IntHout et al., 2016).

4.8 Implications of findings

There is a need to increase and improve access to and the quality of mental healthcare in the US (Power et al., 2005) and reduce the stigma associated with mental disorders (Griffiths et al., 2014). A study looking at health care, found that 83% of the individuals who died by suicide, received healthcare in the year before their death, but half of them did not have a mental disorder diagnosis (Ahmedani et al., 2014) and only 25.7% had contact with inpatient or outpatient mental health services (Fredrik A. Walby et al.,
2018). Also, digital health gives hope for improving access to, and quality of, mental health care (Naslund et al., 2017). An example is the self-guided digital interventions which are designed to be used without an expert guidance and used through online programmes or mobile applications (Torok et al., 2020). This innovative approach offers the opportunity to reach individuals who do not access conventional health care services (Torok et al., 2020) including those from a low-income and middle-income countries (Naslund et al., 2017).

In addition, gun violence and suicide could be addressed from a population-wide approach (Kaplan and Mueller-Williams, 2019). For instance, introducing federal regulations directed to decreasing firearm prevalence would be useful in preventing firearm suicide at the population level (Kaplan and Mueller-Williams, 2019). However, since there is no consensus over the causes of gun violence, including suicide by firearm, and that multiple biopsychosocial factors likely play a role in exacerbating it, policies created to address the problem are controversial (Smith and Spiegler, 2020). For example, some groups propose policies to limit access to firearms, while others propose to improve access to mental health services (Smith and Spiegler, 2020). Although there are still gaps in our knowledge about associations between mental disorders and firearm suicide, our findings may encourage future researchers to continue exploring the factors that contribute to suicide by firearm.

4.9 Conclusion

The objective of this systematic review was to determine whether mental disorders are linked to suicide by firearm. While at face value, our results suggest that having a mental disorder may not be consistently associated with the odds of dying by suicide
using a firearm, in reality, the substantial heterogeneity and high risk of bias preclude any definitive conclusions. Therefore, further research in this field is needed, particularly in studies focused on investigating this link among specific mental disorders and improving the measurement of the exposure. The findings of such work would better advise disclosure and evaluation of those at higher risk and allow suitable therapeutic and suicide preventive interventions to be established.

**Author Statement**

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**Conflict of interest**

**The authors declare no conflict of interest**

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