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Review article

The lethality of suicide methods: A systematic review and meta-analysis

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ABSTRACT

Background: The use of suicide methods largely determines the outcome of suicide acts. However, no existing meta-analysis has assessed the case fatality rates (CFRs) by different suicide methods. The current study aimed to fill this gap.

Methods: We searched Scopus, Web of Science, PubMed, ProQuest and Embase for studies reporting method-specific CFRs in suicide, published from inception to 31 December 2020. A random-effect model meta-analysis was applied to compute pooled estimates.

Results: Of 10,708 studies screened, 34 studies were included in the meta-analysis. Based on the suicide acts that resulted in death or hospitalization, firearms were found to be the most lethal method (CFR:89.7%), followed by hanging/suffocation (84.5%), drowning (80.4%), gas poisoning (56.6%), jumping (46.7%), drug/liquid poisoning (8.0%) and cutting (4.0%). The rank of the lethality for different methods remained relatively stable across study setting, sex and age group. Method-specific CFRs for males and females were similar for most suicide methods, while method-CFRs were specifically higher in older adults.

Conclusions: This study is the first meta-analysis that provides significant evidence for the wide variation of the lethality of suicide methods. Restricting highly lethal methods based on local context is vital in suicide prevention.

1. Introduction

In 2019, more than 700,000 people died by suicide globally. According to the latest report by World Health Organization (2021), more than one in every 100 deaths in 2019 were due to suicide. The number of suicide deaths was higher than that due to HIV/AIDs, breast cancer, malaria, war or homicide. To date, understanding the cause of suicidal behaviors still remains a puzzling challenge due to the complex interaction of multiple neurological, psychological and social factors (Franklin et al., 2017; De Berardis et al., 2018; Orsolini et al., 2020; Stack, 2000a, 2000b).

An interesting phenomenon in suicide is that the demographic profiles in suicide deaths and suicide attempts are often reported as being very different. Studies have consistently found that suicide rates are usually higher for males, and increase with age, while suicide attempts are more likely to be found among females and young people (Hawton and Harriss, 2008; Conner et al., 2019; Lee et al., 2014; Miller et al., 2004). This discrepancy suggests that the majority of people who attempt suicide do not die by suicide. The outcome of suicide acts largely depends on the method used. A population-based study in the US showed that the likelihood of suicide attempts resulting in death varies by method, ranging from a high of 90% for firearms to a low of 0.7% for cutting (Conner et al., 2019). Generally, methods that are possibly interrupted or aborted during the suicide attempts (e.g. cutting, poisoning) were less lethal than the methods that would immediately cause death (e.g. firearms or jumping), as they offer a wider window of opportunity for rescue or for attempters to change their minds (Barber and Miller, 2014b).

Understanding the likelihood of death from suicide acts using different methods by calculating case fatality rates (CFRs) is essential when developing evidence-based suicide prevention strategies. However, such estimates require population-based registries of both method-specific suicide deaths and suicide attempts. To date, there is no universal surveillance system for suicide attempts. Most studies that

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estimated CFRs for suicide have relied on hospital records alone, or hospital records supplemented by information from community sources (e.g. records from police or suicide prevention centres) (Conner et al., 2019; Miller et al., 2004; Cibis et al., 2012; Chen et al., 2009; Pfeifer et al., 2020). Although the number of studies in this field has increased, study providing summary estimates of the lethality for different suicide methods was lacking. To fill this gap, we conducted a systematic review and meta-analysis to estimate the CFRs for different suicide methods, and to examine whether the CFRs associated with specific suicide methods differed by economic region, sex or age group. The aim of this review is to generate the first-known empirical evidence on the role that suicide methods play in suicide deaths, and to better inform suicide prevention strategies.

2. Methods

2.1. Reporting framework and study protocol

This study was reported in accordance with Preferred Reporting Items of Systematic Reviews and Meta-Analysis (PRISMA) (Page et al., 2021). The protocol for this review was registered with PROSPERO (CRD42020218211).

2.2. Search strategy

We searched Scopus, Web of Science, PubMed, ProQuest, and Embase for articles published from inception to 31 December 2020. The keywords for the search included "suicide", "lethality", "case fatality", and "method", and we did not apply any language restrictions. The search terms are provided in Supplement Table 1S. We also scrutinized the reference lists of all relevant articles to identify other potentially relevant publications.

2.3. Inclusion and exclusion criteria

Any peer-reviewed epidemiological study was eligible for inclusion if it reported CFRs, or reported sufficient data to enable calculation of CFRs, by different suicide methods. From our knowledge of the area, we anticipated that these methods might include firearm, hanging/suffocation, drowning, jumping, gas poisoning, cutting or drug/liquid poisoning. We excluded (1) studies that investigated or compared risk factors for suicide acts and suicide deaths rather than assessing their prevalence; (2) studies that reported survival rates by following up on a specific group of people; (3) studies that did not report sufficient information for extraction or calculation of method-specific CFRs; (4) studies reporting on data which had been published in an already-included publication; and (5) studies which incurred a high risk of bias (poor study quality) (see later section).

2.4. Study selection

Two authors (ZYC and QSC) independently assessed the relevance of each study. Firstly, titles and abstracts of potentially-relevant articles were screened, and then full texts of those articles retained after initial screening were reviewed for further assessment. Disagreements were resolved by discussion between these authors, and unresolved conflicts were addressed by an independent author (PSFY).

2.5. Study quality assessment

The methodological quality of included studies was independently appraised by two authors (ZYC and AJ) using the tool developed by Hoy et al. (2012) (see Supplement material Table 5S). Dichotomous scoring was assigned to each item, and an overall quality score ranging from 0 to 9 was generated by summing scores across items. Study quality was classified as low (<=3), moderate (3–6), and high (>=7) risk of bias. In case of disagreement, consensus was reached through discussion, and where conflict remained, it was again resolved by an independent author (PSFY). Studies were excluded from analysis if they were classified as having high risk of bias.

2.6. Data extraction

Data were independently extracted from the included studies by two authors (ZYC and AJ) using a structured form. This included publication information (author, year of publication); study characteristics (study period, study location, study setting, data source, sample, counting unit of suicide attempts); demographics (sex, age group); suicide methods (firearm, hanging/suffocation, drowning, jumping, gas poisoning, drug/liquid poisoning or cutting); and outcome variables (number of suicide deaths, number of suicide attempts, CFR). All extracted data were checked by a third investigator (QSC) and disagreements were resolved through consensus.

We referred to fatal, and non-fatal, intentional self-inflicted injures as suicide death, and suicide attempts, respectively. All the intentional self-inflicted injures (irrespective of the fatality of the outcome) were referred to as suicidal acts. CFR was defined as the proportion of suicide deaths in the total number of suicidal acts (CFR calculated as the number of suicide deaths/ [number of suicide deaths + number of suicide attempts]). For example, Connor et al. (2019) studied American data from 2007 to 2014 on the method of suicide in 309,377 fatal suicide attempts and 3348509 non-fatal suicide attempts. For the subgroup of suicide acts with firearms, there were 175,189 cases. Fully 156,901 of these suicide acts ended up as suicide fatalities or deaths, while only 18,288 suicide acts with guns were non-fatal. The CFR for firearms in this study, therefore, should be 89.6% (156,901/ 175,189).

If the number of suicide attempts was estimated from hospital records (e.g. emergency department, hospitalization or both), we coded the setting as clinic-based. If the data sources used to estimate suicide attempts included non-hospital records (e.g. police records, community mental health centers, community surveys), we coded the setting as community-based. Some studies counted the number of suicide attempts based on the number of episodes, while some were based on the number of attempters. We coded this as the counting unit of suicide attempts. Studies were classified from high-income countries, and low- and middle-income countries based on the World Bank classification (The World Bank, 2021). For studies reporting aggregate data during a study period, as well as the data for individual years, we extracted the time-aggregate data from the longest available period, rather than the year-specific data.

2.7. Data synthesis and analysis

We recalculated the CFRs with 95% confidence intervals (CIs) based on the crude numerator and denominator information reported in each included study. For studies that did not directly report information on the number of suicide deaths or suicide attempts, we estimated these based on available data. The CIs around individual study CFRs were calculated using the Clopper-Pearson method (Clopper and Pearson, 1934). Pooled CFRs were computed using the random-effect meta--analysis model with Freeman-Tukey double arcsine transformation (Barendregt et al., 2013). Between-study variance was estimated by the restricted maximum-likelihood method and the I^2 statistic was used to indicate the proportion of total variation due to heterogeneity (Veroniki et al., 2016). Publication bias was assessed by Egger et al.'s (1997) test.

At first, we pooled the CFRs by different suicide methods using the studies that reported method-specific CFRs in the general population. We stratified the analysis by setting, as different study samples contributed different denominators to calculate CFRs. A sensitivity analysis including only those studies with low risk of bias was conducted to assess the robustness of our findings. A meta-regression was applied to compare the CFRs associated with different suicide methods after

adjusting for other potential covariates. We further estimated the method-specific CFRs by country income level, sex and age group, to test whether CFRs differed by these factors within the same suicide method categories. All data analyses were performed in R version 4.0.2 with the package "meta" and "metafor" (Schwarzer, 2007; Viechtbauer, 2010).

3. Results

3.1. Characteristics of the included studies

We identified 10,708 records through primary database searching. After removing duplicates, 3788 records remained. The full texts of 155 studies were assessed for eligibility after screening titles and abstracts and an additional 17 studies were identified from references lists. We further excluded 138 articles that did not fulfill inclusion criteria, and the remaining 34 articles were included in the final meta-analysis (Wang et al., 2020; Tong et al., 2020; Pfeifer et al., 2020; Miller et al., 2020; Gomez et al., 2020; Daly et al., 2020; Tessler et al., 2019; Mejías-Martín et al., 2019; Conner et al., 2019; Geulayov et al., 2018; Sun et al., 2015; Mergl et al., 2015; Lee et al., 2014; Anestis and Bryan, 2013; Yip et al., 2012b; Spittal et al., 2012; Saberi-Zafaghandi et al., 2012; Razaeian and Sharifirad, 2012; Cibis et al., 2012; Hawton et al., 2010; Jansen et al., 2009; Chen et al., 2009; Elnour and Harrison, 2008; Recena et al., 2006; Hempstead, 2006; Vyrostek et al., 2004; Miller et al., 2004; Le Pont et al., 2004; Eber et al., 2004; Shenassa et al., 2003; Spicer and Miller, 2000; Sadowski and Munoz, 1996; Centers for Disease Control Prevention, 1995; Van Casteren et al., 1993). The PRISMA flowchart is reported in Fig. 1.

Of the 34 included studies, 27 (79%) had low risk of bias and the remaining seven (21%) had moderate risk of bias. The included studies came from 18 countries/territories, with the majority of studies (85%) from high-income countries. Fifteen studies were conducted in the Americas, ten in Europe, seven in Asia, and two in Oceania. There was no study from Africa that fulfilled our inclusion criteria. Twenty-five studies (74%) reported suicide attempt data collected in clinical setting, in which six studies used hospitalization records only, and 19 studies used hospital records including those from emergency departments. Most studies used suicide episodes as the counting unit (91%), and population-representative samples (82%). Thirty-one studies (91%) reported method-specific CFRs among the general population. Of these, 15 studies reported method-specific CFRs by sex and 11 studies reported method-specific CFRs by age group. Three studies (9%) focused on method-specific CFRs in only young people. Detailed information about the characteristics of the included studies is provided in Supplement material Table 2S.

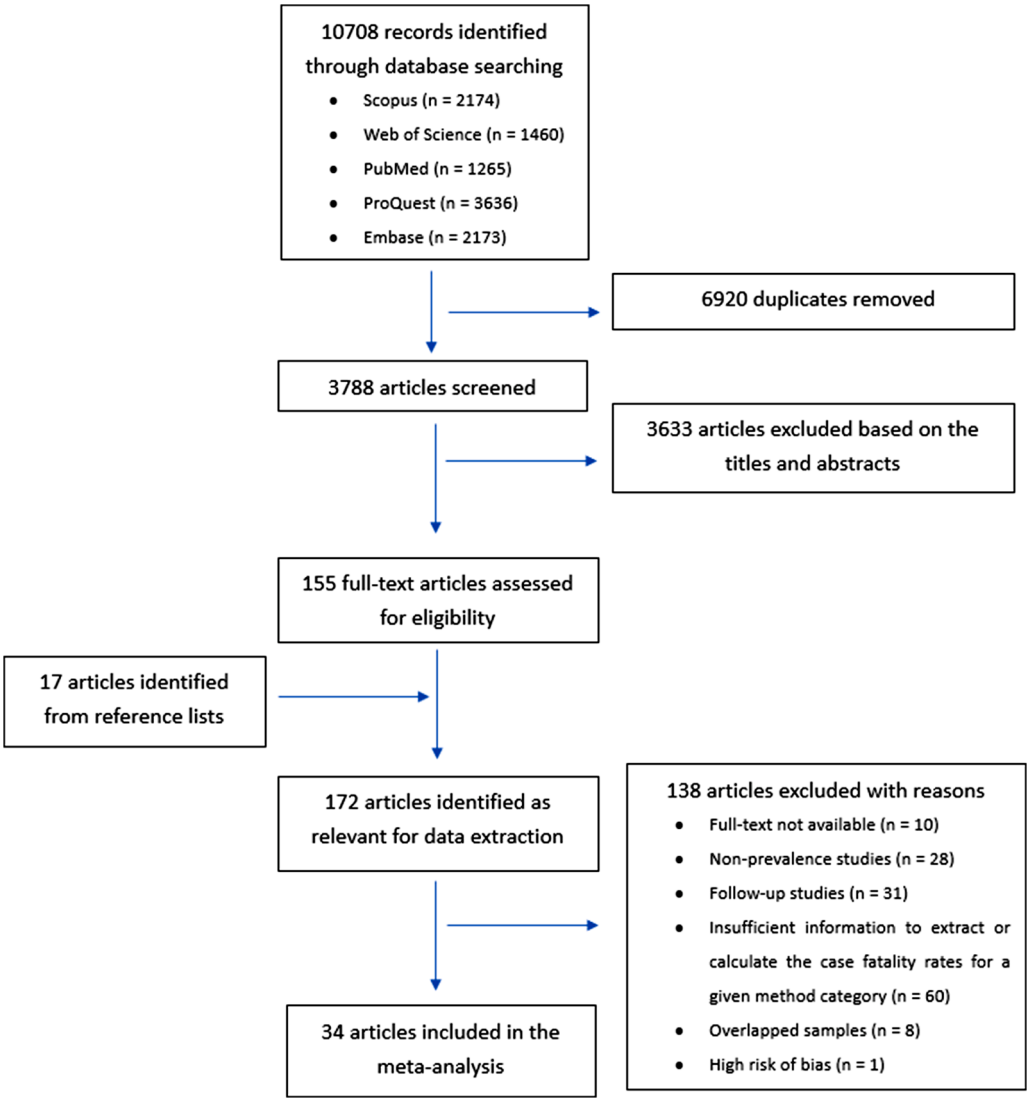

Fig. 1. PRISMA flow diagram.

3.2. CFRs by suicide method

Fig. 2 reports on the pooled CFRs for different suicide methods among the general population, stratified by setting. CFRs extracted from individual studies can be found in Supplement material Fig. 2S. Based on the suicide acts resulting in death or hospitalization, firearms were the most lethal method, with an estimated CFR of 89.7% (95%CI: 82.0–95.5), followed by hanging/suffocation (CFR: 84.6%, 95% CI: 73.5–93.1), drowning (CFR: 80.4%, 95% CI: 77.1–83.5), gas poisoning (CFR: 56.6%, 95% CI: 45.0–67.9), and jumping (CFRs: 46.7%, 95% CI: 22.1–72.7). However, the CFRs of drug/liquid poisoning and cutting were relatively low, at 8.0% (95% CI: 0.0–29.1) and 4.0 (95% CI: 2.5–5.9), respectively. When using the samples that included suicide attempts treated in hospital emergency departments, or suicide attempts identified in community setting, we consistently found a wide range of CFRs associated with different suicide methods. Firearms was the most lethal method with CFR 86% (95% CI: 81.3–90.1) in clinical setting including emergency department and 75.8 (95% CI: 66.8–83.8) in community setting. Less lethal methods were drug/liquid poisoning and cutting (CFRs less than 6%). Results from the meta-regression showed that after adjusting for study characteristics (study setting, mid-year of study period, sample, counting unit of suicide attempts, country income level), there was a clear hierarchy regarding the lethality of methods (Supplement material Table 3S). The CFR for firearms was significantly higher than all other methods, followed by hanging/suffocation and drowning, and then by jumping and gas poisoning. The CFRs of drug/liquid poisoning and cutting were similar, and significantly lower than other methods. In general, studies conducted in clinical setting using only hospitalization records to estimate suicide attempts reported the highest CFRs, compared with those using data sources that included emergency department records or information from community setting.

3.3. Method-specific CFRs by country income level

Table 1 reports the subgroup analysis on method-specific CFRs by country income level. There were only few studies reporting method-specific CFRs in low- and middle-income countries. Based on the studies conducted in clinical setting, the CFRs for hanging/suffocation and drug/liquid poisoning in low- and middle-income countries were significantly higher than in high-income countries. One study using an inpatient sample in low- and middle-income countries reported that the CFR for drug/liquid poisoning was 43.6% (95% CI: 41.3–45.9). Even considering the suicide attempts treated in emergency departments, the CFRs by this method in low-middle income countries were relatively higher, estimated to be 10.2% (95% CI: 7.8–13.0), compared with 2.4% (95% CI: 1.5–3.6) in high-income countries.

3.4. Method-specific CFRs by sex and age group

There were no significant sex differences in CFRs when considering each suicide method, except for cutting (Table 2). For males and females, and across settings, firearms and hanging/suffocation were consistently reported as the most lethal methods, while drug/liquid poisoning and cutting were least lethal. The all-method CFRs in males were significantly higher than females. The highest all-method CFRs were found for older adults in all settings. For most suicide methods, different age groups had different likelihoods of dying, even if they used the same method (Table 3). For instance, the CFR for drug/liquid poisoning among older adults, estimated by the data including emergency department samples, was 5.1% (95% CI: 4.2–6.0), which was significantly higher than the CFR of 0.4% (95% CI, 0.2–0.7) for young people. Although young people were less likely to die from their suicide acts, their probability of death by using firearms remained high, with CFR of 77.8% (95% CI: 70.3–84.4).

3.5. Sensitivity analysis and publication bias

Sensitivity analysis identified that one study with moderate risk of bias elevated the pooled CFR for drug/liquid poisoning in the sample drawn from hospitalization records. After removing this study, the CFR for drug/liquid poisoning dropped to 2.0% (95% CI: 1.4–2.6). The remaining pooled estimates remained similar to those from the crude analyses (Supplement Fig. 1S). Publication bias was assessed for the estimates pooled from at least ten studies, and no significant publication bias was detected by the Egger's test (Supplement material Table 4S).

4. Discussion

4.1. Main findings

This review found that in general, studies using only hospitalization data reported higher method-specific CFRs than those using data from broader sources (e.g. emergency departments, or community data sources). The higher CFRs could be explained by the fact that hospitalization data only captured those suicide attempts resulting in the most severe injuries. Therefore, denominators for calculating CFRs estimated by hospitalization data were often smaller. Although the method-specific CFRs estimated by different study settings varied to some extent, the lethality ranking for different methods remained relatively stable across study settings. Methods that were most frequently resulting in death were firearms, followed by hanging and drowning. Cutting was least frequently lethal. However, for suicide acts involving drug/liquid poisoning, the CFRs varied across country economies. The percentage of deaths from this method in low- and middle-income countries was considerably higher than that in high-income countries. This might be because in low-and middle-income countries, readily-accessible pesticides and other agricultural chemicals are often used in suicide acts, and on average, these are more lethal than the psychotropic and analgesic medications that are frequently used in self-poisoning in high-income countries (Tong et al., 2020; Eddleston, 2000). Moreover, the medical care and health facilities for rescue services for self-poisoning in low- and middle-income countries may be more insufficient than those in high-income countries, which might contribute to the higher CFRs (Eddleston, 2000).

The all-method CFRs were higher for males than females, and tended to increase with age. However, when comparing the method-specific CFRs between males and females, there were few differences, which indicated that the overall higher CFR for males was presumably because the suicide methods that men used were more likely to be lethal (Conner et al., 2019; Miller et al., 2004, 2012). However, the age disparity in method-specific rates was pronounced. This might be explained by the physical vulnerability and fragility of older adults, compared to younger people, which would increase the likelihood of a fatal outcome from physical injury from suicide attempts regardless of the method (Conner et al., 2019; Chen et al., 2009; Spicer and Miller, 2000).

Among all the included studies, of note was that only five studies were from low- and middle-income countries, despite the fact that these countries contribute more than 60% globally to suicide deaths (World Health Organization, 2021; Yip et al., 2021). This indicates the need for more research attention on method-specific CFRs in suicide in low- and middle-income countries.

4.2. Implication for suicide prevention

Death by suicide can potentially be prevented in two broad ways: by reducing the incidence of suicide acts and by reducing case fatality (Yip et al., 2012a). The former, which is the prime paradigm in current suicide prevention strategies, usually focuses on how to remove the upstream cause of suicidal behaviors. However, mitigating the causes of suicidal behaviors in practice is difficult due to the complex and diverse nature of factors that contribute to suicidal behaviors. An additional,

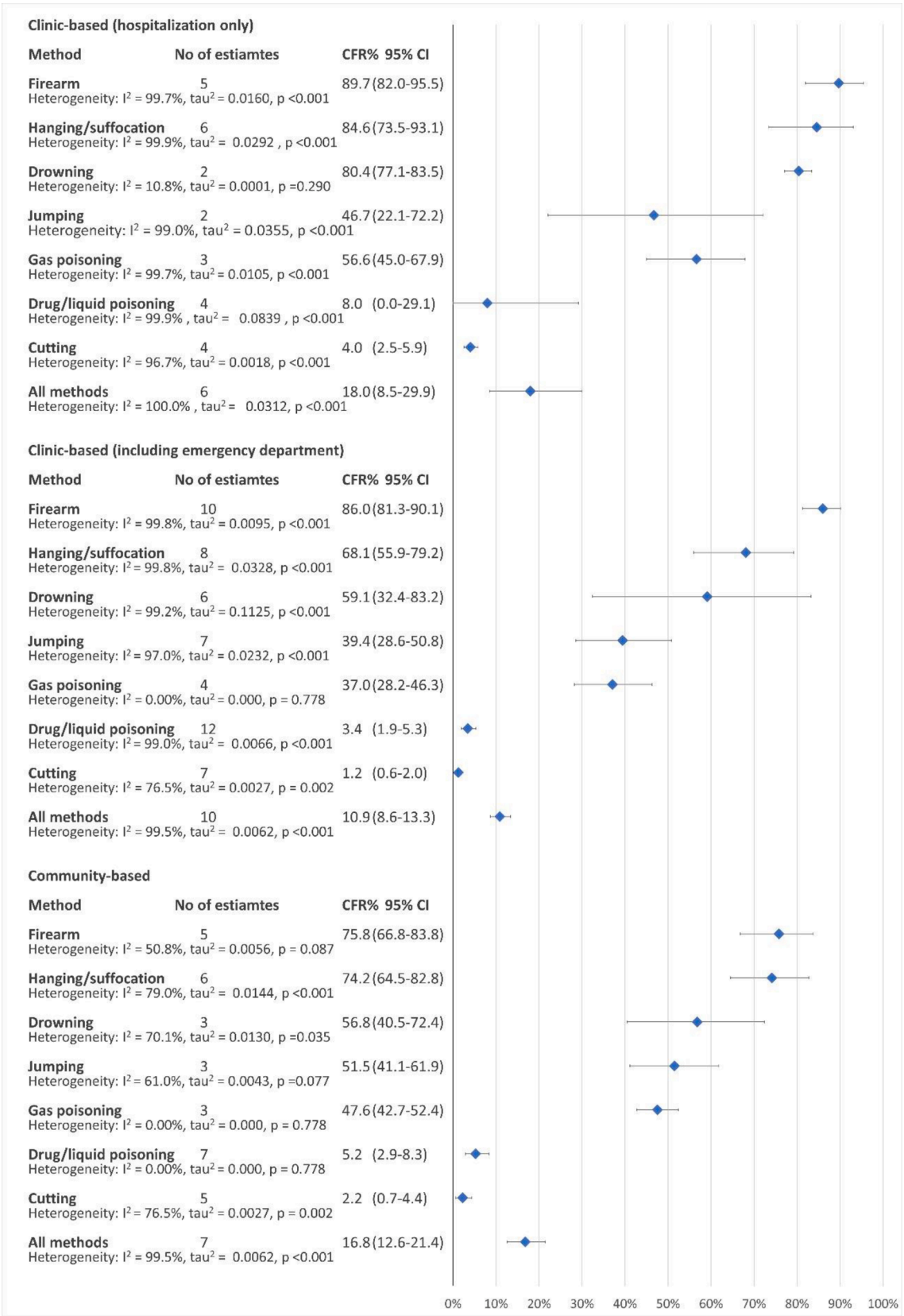

Fig. 2. Case fatality rates for different suicide methods.

Table 1
Method-specific CFRs in suicide, by income level.

	High-income			Low- and middle-income				
Method	No of estimates	CFR% (95% CI)	I^2	No of estimates	CFR% (95% CI)	I^2	Q_b	*p*
Clinic-based (hospitalization only)								
Hanging/suffocation	5	81.1 (70.3–89.9)	99.9%	1	97.2 (95.4–98.6)	–	16.43	<0.001
Drug/liquid poisoning	3	2.0(1.4–2.6)	99.5%	1	43.6 (41.3–45.9)	–	1278.50	<0.001
All methods	5	13.1 (9.1–17.7)	100.0%	1	48.9 (46.9–50.8)	–	143.10	<0.001
Clinic-based (including emergency department)								
Drug/liquid poisoning	10	2.4 (1.5–3.6)	99.6%	2	10.2 (7.8–13.0)	85.6%	36.34	<0.001
Cutting	6	1.2 (0.7–1.9)	93.5%	1	4.9 (0.6–12.1)	–	3.86	0.049
All methods	9	10.6 (8.2–13.2)	99.8%	1	13.7 (11.8–15.7)	–	3.55	0.060
Community-based								
Firearm	3	80.5 (63.8–93.3)	57.8%	2	71.6 (63.4–79.1)	15.7%	0.81	0.367
Hanging/suffocation	4	72.7 (55.9–86.7)	87.4%	2	76.7(74.3–79.0)	0.0%	0.26	0.609
Drug/liquid poisoning	5	6.0 (2.7–10.4)	97.8%	2	3.7 (1.4–6.9)	97.0%	0.99	0.320
Cutting	3	2.6 (0.6–5.9)	87.1%	2	2.2 (1.1–3.7)	0.0%	0.47	0.491
All methods	5	17.6 (15.7–19.5)	80.5%	2	15.2 (2.3–36.4)	99.8%	0.07	0.794

Note: Methods with missing data in subgroup were not shown in the table.

Table 2
Method-specific CFRs in suicide, by sex.

	Male			Female				
Method	No of estimates	CFR% (95% CI)	I^2	No of estimates	CFR% (95% CI)	I^2	Q_b	*p*
Clinic-based (hospitalization only)								
Firearm	1	96.5 (96.0–97.0)	–	1	95.9 (94.2–97.4)	–	0.57	0.449
Hanging/suffocation	1	90.7(89.4–91.9)	–	1	89.0 (85.9–91.7)	–	1.36	0.244
Cutting	1	9.9 (8.4–11.6)	–	1	2.6 (1.7–3.6)	–	59.48	<0.001
All methods	5	30.9 (19.5–43.5)	99.9%	5	10.8 (2.0–25.4)	99.8%	4.53	0.033
Clinic-based (including emergency department)								
Firearm	4	83.8 (73.6–91.9)	99.1%	4	68.1 (44.6–87.8)	96.3%	2.08	0.149
Hanging/suffocation	5	72.3 (55.7–86.3)	99.8%	5	60.1 (40.3–78.4)	99.4%	0.93	0.336
Drowning	3	49.2 (7.2–92.0)	99.2%	3	46.3 (6.8–89.0)	98.3%	0.01	0.935
Jumping	4	41.3 (25.4–58.1)	92.7%	4	33.0 (17.8–50.4)	92.6%	0.46	0.498
Gas poisoning	2	43.9 (25.0–63.7)	97.2%	2	26.9 (15.8–39.6)	89.7%	2.09	0.149
Drug/liquid poisoning	8	4.3 (2.0–7.5)	99.4%	8	2.4 (1.0–4.6)	99.3%	1.31	0.252
Cutting	4	1.4 (0.5–2.6)	82.3%	4	0.0 (0.0–0.1)	74.5%	18.76	<0.001
All methods	10	18.0 (14.7–21.5)	99.6%	10	5.1 (3.6–6.9)	99.3%	50.20	<0.001
Community-based								
Firearm	4	75.8 (60.0–89.0)	57.4%	3	71.0 (38.6–96.1)	0.0%	0.31	0.576
Hanging/suffocation	5	77.7 (64.0–89.0)	80.9%	4	58.6 (44.8–71.9)	49.0%	4.10	0.043
Drowning	3	77.5 (50.9–96.7)	46.5%	2	65.4 (49.2–80.2)	0.0%	0.56	0.454
Jumping	3	55.2 (46.4–63.8)	31.3%	2	42.3 (32.0–52.9)	0.0%	3.37	0.066
Gas poisoning	2	47.0 (29.3–65.0)	0.0%	2	34.8(11.2–61.9)	0.0%	0.49	0.486
Drug/liquid poisoning	5	9.1 (4.8–14.6)	90.4%	4	5.1 (3.0–7.5)	83.2%	2.74	0.098
Cutting	3	3.5 (0.0–10.2)	57.0%	3	0.0 (0.0–1.1)	2.2%	1.92	0.166
All methods	7	25.4 (17.2–34.7)	99.5%	7	10.4 (5.8–16.0)	99.0%	9.07	0.003

Note: Methods with missing data in subgroup were not shown in the table.

and often neglected strategy is to reduce the lethality of suicide acts by reducing access to highly lethal suicide methods. This strategy can reduce suicide rates substantially without necessarily changing underlying suicidal behaviors (Barber and Miller, 2014b; Yip et al., 2012a).

Firearms, found in our analysis to be the most lethal suicide method, should be the target for method restriction, especially in countries where firearms are easily accessible and commonly kept in private households (e.g. USA). Physically restricting access to firearms such as by safe (locked) storage, and lethal means counselling advising families and friends to keep firearms away from at-risk persons are promising to reduce firearm suicides effectively (Barber and Miller, 2014b; Mann and Michel, 2016). An intervention in Israel showed that by reducing soldiers' access to firearms on weekends, firearms suicide, as well as the overall suicide rate in Israeli Defense Forces dropped significantly (Lubin et al., 2010). A study estimated that if one-quarter of households in the USA could effectively keep firearms away from at-risk persons, around 3600–3900 lives would be saved in one year if there is no method substitution (Barber and Miller, 2014b, 2014a). Even if method substitution occurs, some lives still can be saved as methods available for substitution are often less likely to be as lethal as firearms. Hanging/suffocation is the second most lethal method. However, physically restricting access to this method is challenging due to the ubiquity of ligature and ligation points. One exception where restricting access to opportunities for hanging will be effective is in institutional settings, like hospital inpatient wards, prisons and police custody, where hanging suicides comprise around 10% of all hanging suicides (Gunnell et al., 2005). In these controlled environments, removing ligature points and commonly-used ligatures (e.g. belts, dressing gown cords or shoelaces) can save lives (Bennewith et al., 2005). In addition to the physical availability, an individual's awareness and acceptability of a particular method would influence the likelihood that it is used. Previous studies have indicated that the internet search of suicide methods, and the

Table 3
Method-specific CFRs in suicide, by age group.

Method	Young (age= < 34 years)			Middle aged (age 35–54 years)			Old adult (age >=55 years)			Q_b	p
	No of estimates	CFR% (95% CI)	I^2	No of estimates	CFR% (95% CI)	I^2	No of estimates	CFR% (95% CI)	I^2		
Clinic-based (hospitalization only)											
All methods	5	9.2 (5.1–14.3)	96.2%	2	22.6 (7.2–43.4)	99.1%	4	42.4 (21.4–65.0)	99.5%	11.99	0.003
Clinic-based (including emergency department)											
Firearm	4	77.8 (70.3–84.4)	98.9%	2	86.6 (82.6–90.2)	97.7%	1	94.4 (94.3–94.6)	–	56.48	<0.001
Hanging/ suffocation	5	32.0 (12.0–55.8)	99.8%	2	64.9 (60.6–69.2)	94.6%	2	80.2 (70.2–88.6)	76.5%	15.77	<0.001
Drowning	2	21.9 (0.0–68.4)	73.4%	1	61.3 (59.2–63.4)	–	1	71.1 (68.8–73.4)	–	40.80	<0.001
Jumping	3	12.2 (0.0–35.9)	83.5%	1	31.5 (30.5–32.5)	–	2	67.0 (40.7–88.8)	80.3%	9.83	0.007
Gas poisoning	3	21.7 (11.4–34.1)	63.2%	1	32.2 (31.5–33.0)	–	2	61.3 (29.8–88.5)	87.6%	5.87	0.053
Drug/liquid poisoning	5	0.4 (0.2–0.7)	96.2%	2	2.6 (2.4–2.8)	88.5%	3	5.1 (4.2–6.0)	95.0%	159.37	<0.001
Cutting	4	0.1 (0.0–0.2)	95.1%	2	1.1 (0.9–1.4)	88.2%	1	4.9 (4.7–5.1)	–	570.92	<0.001
All methods	11	4.3 (2.6–6.4)	99.9%	3	12.2 (8.2–16.9)	99.5%	8	31.2 (28.0–34.4)	99.6%	173.59	<0.001
Community-based											
Hanging/ suffocation	2	31.5 (0.0–100.0)	96.7%	–	–	–	1	86.4 (68.3–98.1)	–	1.20	0.274
Gas poisoning	2	40.4 (31.5–49.5)	0.0%	1	53.9 (46.0–61.6)	–	2	34.0 (0.0–92.4)	60.5%	4.84	0.089
Drug/liquid poisoning	1	2.9 (0.6–6.6)	–	–	–	–	1	28.4 (19.4–38.3)	–	31.48	<0.001
Cutting	2	0.1 (0.0–2.7)	82.7%	–	–	–	1	0.0 (0.0–23.2)	–	0.45	0.504
All methods	5	4.6 (1.1–10.4)	100.0%	2	12.4 (10.4–14.4)	68.3%	3	36.9 (32.8–41.2)	0.0%	135.78	<0.001

Note: Methods with missing data in subgroup were not shown in the table.

high-profile reporting of the methods by the media would lead to common knowledge about its use (Elise et al., 2017; Niederkrotenthaler et al., 2020; Biddle et al., 2016; Yip et al., 2013). For lethal methods that are difficult to be physically restricted such as hanging, reducing cognitive access may be a feasible and effective approach (Barber and Miller, 2014b; Biddle et al., 2010; Baker et al., 2013; Gunnell et al., 2005). Efforts to do so requires collaboration with different stakeholders including government, internet companies and mess media to implement cyber regulation and responsible reporting of suicide. Although the overall CFR for drug/liquid poisoning was considerably lower than that for many other methods, ingesting pesticides was more lethal than ingesting medications (Eddleston et al., 2006; Eddleston, 2000). Given that there is a large base rate of suicide acts involving toxic pesticides in low- and middle-income countries, which is closely related to agricultural practices, a small reduction of CFR for pesticide poisoning will potentially have a considerable impact on the reduction of pesticide-related suicides (Gunnell and Eddleston, 2003). Previous experience in Sri Lanka has shown that after banning several of the most toxic pesticides, the overall suicide rates decreased by half mostly due to the decrease of pesticide suicide, even though the attempts by poisoning by other substances increased (De Silva et al., 2012; Gunnell et al., 2007). Initiatives to reduce the availability of highly-hazardous pesticides (such as restricting their production), and developing and promoting the use of less toxic pesticides are important suicide prevention strategies in low- and middle-income countries.

Evidence-based suicide prevention strategies rely on accessible, current and valid data. Establishing reliable surveillance infrastructure is also an important component in suicide prevention efforts. Given that most severe suicide attempts are treated in hospitals, countries and local health sectors should establish hospital-based surveillance systems that routinely record data on suicide attempts, which can be integrated with death registration data to monitor the changes in incidence, CFRs and the demographic profile of different suicide methods.

4.3. Limitations

This study has several important limitations that must be considered in interpreting the findings. The first limitation is that we observed substantial heterogeneities in our meta-analyses that cannot be fully explored. This might be because (1) the tools used for screening suicide attempts, as well as the hospital admission threshold for suicide attempts, varied across studies and (2) the CFRs for specific methods may vary depending on the context. For instance, suicide attempts by jumping in urban areas are often more lethal than in rural areas, as high buildings are more available in urban areas. However, these variations cannot be fully explored due to the insufficient information in the current literature.

The second limitation concerns the validity of the reviewed studies that inform our estimates, which is a typical limitation for any meta-analysis. Suicide attempts among populations are difficult to capture comprehensively, especially those which result in minor or no injuries and are not presented for healthcare. Thus, we anticipate the possibility that studies included in our analyses might have underestimated the number of suicide attempts and thus overestimated the CFRs. In this regard, we anticipate that overestimations of CFRs were more pronounced for less lethal methods such as drug/liquid poisoning and cutting. On the other hand, suicide deaths by some methods such as drug overdose were often misclassified as accidental or undetermined deaths. It is also possible that the CFR would be higher if drug overdoses, a form of self-injury mortality containing some misclassified suicides, were taken into account (Rockett et al., 2020).

Third, there was the potential for missing data. Although we

searched the reference lists of all relevant articles, it was possible that some papers were missed due to inadequate description of the research in the title and abstract, or where electronic versions of the papers were unable to be obtained. Besides, we have not approached the authors of the papers which we excluded when there had not been enough information to extract CFRs.

We also acknowledge that some subgroups had limited data for analysis, which may potentially bias our results. Further research incorporating more data from low- and middle-income countries and different demographic subgroups are required.

5. Conclusion

This review is the first that we know of, to summarize current knowledge on the lethality of different suicide methods overall and across subgroups of country income level, sex and age group. We found remarkable differences in CFRs across suicide methods. Among all suicide methods examined, firearms were the most lethal, with more than 75% of suicide acts resulting in death. The least lethal methods were cutting, with less than 5% of suicide acts proving fatal. The important role of suicide methods in determining the outcome of suicide acts indicated that reducing access to highly lethal methods should be a priority in suicide prevention. Such strategies can be implemented by reducing physical access, reducing lethality or toxicity of a given method and reducing cognitive access according to the nature of targeted methods. It is possible that restricting one method will result in the substitution of other methods. However, as long as the substitution is partial or the substituted methods are less lethal, it still produces a desirable outcome of reducing the number of suicides (Daigle, 2005; Liu et al., 2007; Yip et al., 2012a). Continuous data collection on the incidence and CFRs of suicide acts using different methods is essential to inform and track the progress of suicide prevention efforts.

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Ethics approval statement

All data used in this review were publicly available. Ethical approval was not required.

CRediT authorship contribution statement

Ziyi Cai: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Alvin Junus:** Data curation, Methodology, Validation, Writing – review & editing. **Qingsong Chang:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Paul S.F. Yip:** Conceptualization, Data curation, Funding acquisition, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jad.2021.12.054.

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