

## Review Article

# Identification of Risk Factors for Suicide and Insights for Developing Suicide Prevention Technologies: A Systematic Review and Meta-Analysis

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Suicide is a termite that engulfs close to seven hundred thousand people worldwide each year. Existing work on risk factors that predict suicide lacks statistical associations, does not consider most countries, and has a wide range of risk factor domains. The goal of this systematic review and meta-analysis is to enhance our current understanding of suicidality by identifying risk factors that are most strongly associated with suicide and their impact on developing technological interventions for suicide prevention. A search strategy was carried out on four databases: (1) PsycINFO, (2) IEEE Xplore, (3) the ACM Digital Library, and (4) PubMed, and twenty-five studies were included based on the inclusion criteria. Factors statistically associated with suicide are any diagnosed mental disorder, adverse life events, past suicide attempts, low education level, loneliness or high levels of isolation, bipolar disorder, depression, multiple chronic health conditions, family history of suicide, sexual trauma, and being female. Domain-wise, comorbid disorders, and behavior-related risk factors are most strongly associated with suicide. We present a new hierarchical model of risk factors for suicide that advances our understanding of suicide and its causes. Finally, we present open research directions and considerations for developing suicide prevention technologies.

## 1. Introduction

In the 21st century, suicide has become a global cause of concern. According to the World Health Organization (WHO), about seven hundred thousand people die from suicide worldwide each year [1]. In 2019, one in every hundred deaths was a result of suicide [1]. The global suicide rate is twice as high among men as women [1]. For every suicide death, there are tenfold more suicide attempts [1]. Suicide is a termite that engulfs both the attempter and his or her community. Suicides usually leave families and friends of the individual, spiralling for answers [2]. While the act of suicide itself might appear as an escape from reality [3], the causal pathway to lethal suicidal behavior is manifested in a series of stages [4]. According to the interpersonal theory of suicide [4], suicide can be classified as ideations, communications, and behaviors. The theory suggests that working up to the act of suicide is difficult to do and is a gradual consequence of many stages like passive suicidal ide-

ation that matures into suicidal intent and eventually to lethal suicidal behavior.

Suicidality has been characterized as stages along a continuum starting with death wishes and tiredness of life to suicidal ideation, then to planning, and finally to attempt [5]. Understanding the intricate differences between each of the stages of suicidality is fundamental to the study of suicide research. Suicidal ideation is defined as “thoughts of engaging in behaviors intended to end one’s own life” [6]. Suicide plans are considered as “the cognitive formulation of a specific method through which one intends to die” [6]. Suicide attempts have been defined as “engagement in potentially self-injurious behavior in which there is at least some intent to die” [6]. Suicide death is defined as “death arising from an act inflicted upon oneself with the intent to kill oneself” [7]. Suicide is defined as the “intentional ending of one’s own life” [8]. Risk factor refers to “antecedent conditions associated with an increase in the likelihood of adverse, deleterious, or undesirable outcomes” [9]. In our

work, this undesirable target outcome is any of the stages of suicidality (i.e., suicidal ideation, plan, attempt, or death).

The WHO estimates that over half of all deaths by suicide (58%) occur before an individual reaches the age of 50 years old [1]. Identifying the risk factors of suicide at an early stage can thus enhance suicide prevention efforts. If there is evidence of modifiable risk factors, they can be targeted at the onset. Understanding modifiable risk factors can guide the development of technologies for suicide prevention. Our work analyzes existing research on risk factors for suicide and presents a meta-analysis to derive risk factors having a maximum positive association with suicide and its related outcomes. Using the prominent risk factors identified, we present a new framework to understand the problem of suicide and its causes. Finally, we present open research questions and considerations for developing suicide prevention technologies.

*1.1. Current Knowledge.* Research in the field of “suicide” has spiked in the past decade (Figure 1) with over 15,000 publications concerning “suicide” in 2022 itself. Suicide and suicide risk have been extensively studied [8] to determine geographical and temporal trends relating to suicide. This work [8] explores the mechanisms for suicide, the neurobiology of suicidal behavior, the assessment of risk, and prevention strategies.

Several works including systematic reviews and meta-analyses have studied risk factors of suicide in the general population [10–14], children and adolescents [15–17], young adults [17–24], prisoners [25–28], inpatients [24, 26, 29–31], and older adults [32–34]. Risk factors for suicide have been studied alongside psychiatric conditions like adult attachment [35], depression [23, 32, 36, 37], binge-eating disorder [38], bipolar disorder [15, 26, 39, 40], obsessive-compulsive disorder (OCD) [41], mental disorders [20], psychosis [42], schizophrenia [43, 44], self-harm [21, 27, 45, 46], substance use disorders [24], and physiological health conditions like bladder cancer [31], bariatric surgery [47], human immunodeficiency viruses (HIV) [48], and smoking [49].

Certain studies have analyzed risk factors for suicide in particular demographic contexts like ethnicity or culture [18], gender [17], and poverty [50]; psychosocial contexts like life adversities [11, 19, 37], intimate partner relationships [51], and job stressors [52]; and environmental contexts like natural disasters [53]. Risk factors of an outcome can be derived from diverse domains (e.g., biology, psychology, and sociology) and different levels within a domain (e.g., cognitive processes, personalities, and genetics) [9].

In relation to risk factors for suicide, the biopsychosocial model of suicide risk [8] presents a combination of distal (e.g., family history and early-life adversity), developmental (e.g., personality traits and chronic substance abuse), proximal risk factors (e.g., psychopathology and biological factors), and social context (e.g., sociocultural norms and economic turmoil) as the cause of suicide. A study analyzing survey data in Bhutan [12] has found that young age and alcohol consumption are positively associated with suicidal ideation and suicide attempts. Certain systematic reviews

and meta-analyses have focused on deriving the risk factors specifically for suicide. A systematic review focused on suicidality among Norwegian youth [22] found depression, previous suicidal behavior, alcohol use, and nonintact parental unit to be significant risk factors for suicide and suicide attempts. Another systematic review analyzing suicide risk among rural adults in the US [54] found individual-level factors like access to firearms, alcohol and substance abuse, and economic stress to be strongly related to suicide. Socio-demographic factors were assessed by a study in Europe and America [55]. The authors found unemployment, rural life, marital status other than marriage, and low education to be closely associated with suicide and suicidal behavior. Another systematic review of risk factors worldwide [56] found psychiatric, biological, and psychological factors relating to suicide.

We found very few meta-analyses that provided quantitative associations between risk factors and suicide. In a meta-analysis conducted on the Iranian population [14], social factors like family conflict and marital problems were found to be strongly associated with suicide attempts. Another meta-analysis consisting of only longitudinal studies [57] found associations of suicidality with biological, psychopathological, cognitive, and demographical factors. A meta-analysis focused on demographic factors [58] found no strong association between demographic factors and suicidality worldwide. A meta-analysis of the European general population [10] found female gender, age over 65 years, unemployment, low social support, adulthood adversity, childhood adversity, family history of mental disorder, any affective disorder, major depression, anxiety disorders, tobacco and substance use, any mental disorder, and body mass index to be strongly associated with suicidality.

In recent years, there has been an increase in the use of technology for suicide prevention [59–61]. Suicide prevention interventions involving the use of big data, machine-learning techniques, smartphone applications, wearables, and sensors have been developed [62]. Data-driven approaches collect and analyse large amounts of population data to recognise patterns and predict suicide [62]. Such approaches help in objectively quantifying the impact of different risk factors and how they interact with each other. A study involving 40,000 soldiers in a psychiatric hospital used a machine-learning algorithm to devise a predictive suicide risk algorithm [63]. Another study on South Korean teenage students used data mining techniques to understand the risk factors that led to a suicide attempts [64]. The authors used data mining to identify every possible interaction between a huge range of different variables (i.e., big data). Computerized real-time facial emotion monitoring is also being used to detect subtle changes in the facial expressions of people with suicidal thoughts [65]. Such approaches can help assess suicidality in high-risk individuals who may not disclose their suicidal thoughts verbally.

Computerized therapy and smartphone applications (apps) are also being developed for suicide prevention [62]. For example, a study conducted on 21 Dutch adults assessed a suicide prevention app, Backup, and a small but nonsignificant decrease in suicidal ideation was found [66]. Another

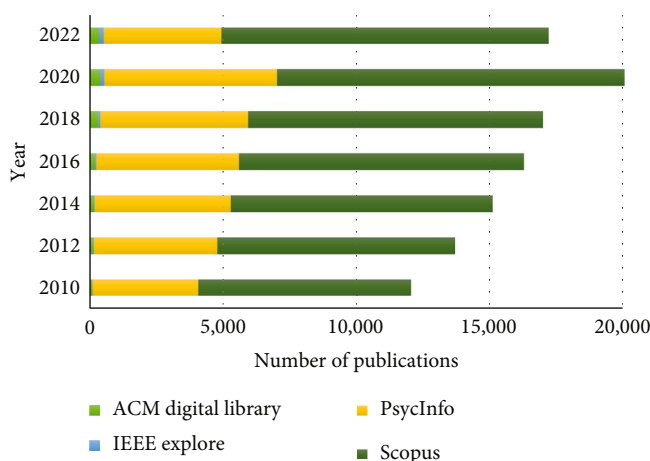


FIGURE 1: Number of publications concerning “suicide” in four databases between 2010 and 2022.

study on 129 psychiatric patients at a Danish hospital evaluated a psychotherapy-based app, LifeApp’tite, with and without clinical treatment [67]. The authors found that the treatment + app group showed a smaller decrease in self-reported suicide risk at the end of the treatment. CALMA, a dialectical behavioral therapy (DBT), a DBT-based app, was designed and evaluated on 18 Argentinian individuals [68]. The app was found to have good acceptability by users and showed a high probability of reducing suicidal ideation, suicidal plan, and self-injurious behaviors postintervention. Furthermore, BlueIce, an app offering a personalized toolbox of strategies for university students with a history of self-harm in the UK, was found to be overall acceptable to students but received mixed responses in terms of standalone usage [69]. SafePlan, a mental health support and safety planning app, was designed and evaluated on students and clinicians in Ireland [70]. Usability results suggest that the app was well received with respect to user confidentiality and interface design being key features of interest. Data from mood-focussed smartphone apps [71] and other biomarkers like blood test and heart rate were combined to create a suicide prediction system [72] and provide crisis management [73–75]. Noninvasive sensors which monitor EEG activity are also being used to create a personalized computer model of an individual’s emotional state [72]. Such sensor-based approaches can be made more robust in combination with physiological measurements from biomarkers, measurements from social interaction using smartphone sensors, patient’s baseline, and clinical data. Thus, different technological approaches can be leveraged to gather rich data about the individual’s complete risk profile which can be monitored to prevent suicide.

*1.2. Research Gap.* Risk factors for suicide have been extensively studied to present frameworks that help us understand suicide, e.g., the biopsychosocial model of suicide risk [8]. However, as this work is a narrative synthesis and not a systematic review or meta-analysis, it does not provide quantitative evidence of an association between the risk factors and suicide. Survey-based studies [12] are prone to underreporting of suicide information because of social stigma relating

to suicide [76]. A majority of the studies found on risk factors for suicide were systematic reviews of specific geographies [22, 54, 55]. Additionally, these studies did not provide statistically significant quantitative associations between risk factors and suicide. In the few meta-analyses conducted [10, 14, 57, 58], publication bias because of language barriers, high heterogeneity, lack of inclusion of temporal risk factors, and lack of coverage of all types of risk factor domains were some of the research gaps that we observed. We also found that there was a high variation in the measurement of risk factors in existing works. We found many researches that investigated digital interventions for suicide prevention, but these solutions were limited in terms of effectiveness, evaluation, and design [62, 77, 78].

In our literature review of existing work, no systematic review and meta analysis of risk factors for suicide were found, which considered all countries and a range of risk factor domains. A meta-analysis of such kind would provide statistical significance of the prominent risk factors of suicide, and in turn, advance suicide prevention efforts. We also did not find any work that used the obtained key risk factors and linked them to existing models explaining suicide. A new model that fits prominent risk factors into the existing framework of the world would help understand the field better. Additionally, considerations for suicide prevention technologies should be based on statistically significant risk factors, and existing work in the field lacks literature that supports this. Our work derives the leading risk factors for suicide and then develops a framework to understand how these risk factors fit into people’s lives. Using the framework, we provide technological considerations that can be incorporated in the design and development stage of suicide prevention technologies. As these considerations for interventions are based on the observed statistically significant risk factors for suicide, they would be crucial for the future development of suicide prevention technologies and can help address the existing gap in terms of effectiveness and design.

Taking these factors into consideration, we formulated the following four research questions to be addressed by our work:

RQ1: What are the different risk factors for suicide?

RQ2: How are the different risk factors statistically associated with suicide? What positive or negative relationships exist between different risk factors and suicide?

RQ3: Which risk factor(s) are most strongly associated with suicide?

RQ4: What are some considerations derived from the risk factor-suicide relationships that can be used to develop effective suicide prevention technologies?

*1.3. Contribution.* Our contributions to the domain of suicide research and preventive interventions are as follows:

- (i) A systematic review and meta-analysis of studies to derive risk factors that have a maximum positive association with suicide and related outcomes. The quantitative associations derived help in understanding the statistical significance of key risk factors
- (ii) An identification of the prominent risk factors into the existing framework of the world and present a new framework to understand the problem of suicide and its causes
- (iii) Suggestion of potential open research questions and considerations for developing suicide prevention technologies

## 2. Materials and Methods

We followed the latest “Preferred Reporting Items for Systematic reviews and Meta-Analyses” (PRISMA) 2020 guidelines [76] for accurate reporting (Figure 2).

*2.1. Search Strategy and Selection Criteria.* On the 3rd of June 2022, we searched the databases PsycINFO, IEEE Xplore, the ACM Digital Library, and PubMed from January 2010 to June 2022. To identify additional studies, we searched the reference list of studies included for full-text and used Google Scholar to identify them. We chose PsycINFO as it is a complete resource for work in the field of psychology, PubMed as it supports literature in the biomedical discipline, and ACM Digital Library and IEEE Xplore as a resource in the field of computing and technology. This ensures good coverage of empirical studies on the topics of interest: suicide, risk factors, suicide prevention, suicide prevention technologies, preventive interventions, and technological interventions. These disciplines were selected for the search because they are the home of most research on suicide, risk factors, and technologies for suicide prevention.

We used various keywords such as “suicide,” “suicidal ideation,” “suicidal thought or thoughts,” “suicidal behavior or behaviors,” “suicidal tendency or tendencies,” “suicide attempt,” “suicide risk,” “suicidality,” “risk factor,” “risk quotient,” “contributing factor,” “relationship between,” and “association between.” We refined our search by using the Boolean terms such as “risk factor and suicide or suicidal behavior or suicidal thought or suicidal ideation.” The search strings are presented in Appendix A (available here).

We further refined the search strings by using more keywords obtained from literature in the search process. We limited our search to articles and full papers (not posters or short papers) published in English.

We selected observational (cohort, case-control, and cross-sectional) studies which include quantitative observations about risk factors associated with suicidal ideation, suicide plan, suicide attempt, and suicide death.

*2.2. Eligibility Criteria.* We included studies that reported “risk” factors for suicide, provided evidence of the association between risk factor and suicide, and had the outcome variable: “suicidal ideation,” “suicide plan,” “suicidal attempt,” or “suicide death.” We focused on studies in English that were based on the general community population.

We excluded qualitative study designs that were not peer-reviewed, had no or inadequate evidence of a correlation between risk factors and suicide, reported protective factors for suicide, and focused on risk factors for psychiatric disorders other than suicide. We also excluded studies that were not observational by design, had duplicate findings, and were unpublished manuscripts, systematic reviews or meta-analyses, or research protocols.

*2.3. Design of Studies and Data Extraction.* Two reviewers from the research team independently screened the records for inclusion in a two-step process. First, the titles and abstracts of retrieved records were screened by the authors. Then, from the relevant articles found, the full text was screened to identify the papers for inclusion in this review. We focused our search on only human studies. During data extraction, we developed the coding scheme for each parameter such that it addressed a particular research question. The coding scheme and corresponding research question for the risk factors’ analysis can be found in Table 1.

We grouped risk factors into the following categories: comorbid disorders and behavior, family and personal psychiatric history, negative life experiences, social and familial characteristics, and sociodemographic characteristics. Four separate outcomes pertaining to suicide were identified: suicidal ideation, suicidal plan, suicide attempt, and suicide death. We have considered the term suicidal ideation as the presence of thoughts relating to suicide or the willingness to die. A suicidal plan refers to plans or actions that support the act of committing suicide. A suicide attempt refers to any displayed behavior or act of attempting suicide. Suicide death includes deaths because of suicide attempted by the individual. Self-harm and nonsuicidal self-injury have not been focused on as primary target outcomes in this review. An additional outcome, “suicide risk” was identified in one of the studies and was considered an overlap of suicidal ideation and suicidal plans.

*2.4. Statistical Analysis.* All statistical analysis was conducted using the statistical software package Stata/SE 17.0 and the metan command. Risk factors that were examined by at least two distinct studies were only considered in the analysis to get a reliable estimate of pooled effect sizes. For a given risk

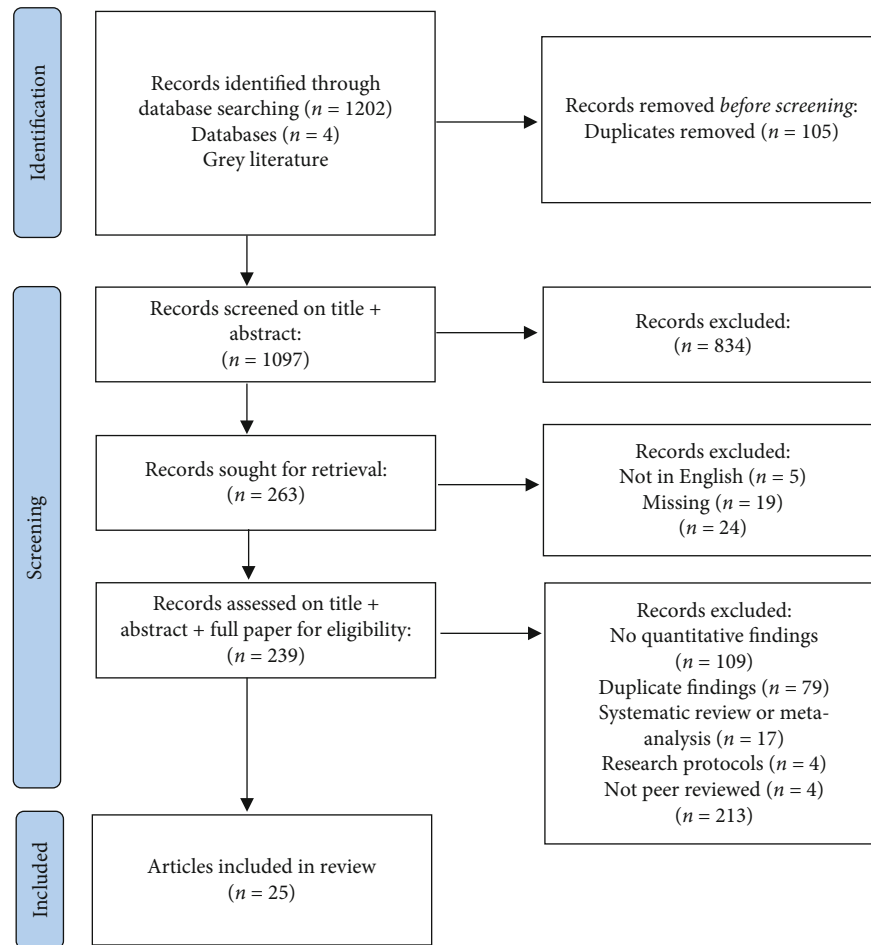


FIGURE 2: PRISMA flow diagram [76] demonstrating the systematic review process undertaken from record identification to the final pool of included articles.

TABLE 1: Risk factors' analysis coding scheme and research question answered by each parameter.

| Identifier                   | Description  | RQ addressed           |
|------------------------------|--|------------------------|
| Basic information            | Title, year, author(s), and keywords   | N/A                    |
| Demographics of participants | Age range of participants (years) and sex  | RQ2 and RQ4            |
| Study country                | Country where the study was conducted  | RQ4                    |
| Period of study              | Duration of study (years)  | RQ2, RQ3, and RQ4      |
| Target population            | Children, adolescents, young adults, adults, inpatient adults, general population, and elderly   | RQ2, RQ3, and RQ4      |
| Suicidality type             | Classification of suicidal behaviors as target outcome of studies (suicidal ideation, suicidal plan, suicide risk, suicide attempt, and suicide death) | RQ2, RQ3, and RQ4      |
| Study design                 | Cohort (retrospective, prospective), cross-sectional, and case-control   | RQ2, RQ3, and RQ4      |
| Total study sample           | Number of participants involved in the study   | RQ2, RQ3, and RQ4      |
| Suicide cases                | Number of participants in the study population diagnosed with either suicidal ideation, suicide attempt, or suicide death                              | RQ2 and RQ3            |
| Assessment tools             | Evaluation tools or scales used in each study for measuring the risk factors   | RQ2, RQ3, and RQ4      |
| Findings                     | Risk factors analyzed in the study and strength of association with the study outcome  | RQ1, RQ2, RQ3, and RQ4 |

factor, odds ratios and their 95% CIs were extracted when reported or calculated using the data available in the study. Studies reported the number of suicides and nonsuicides among participants with and without the risk factor. This data was used to create  $2 \times 2$  contingency tables which were used in the meta-analysis. If a study had insufficient data to use either of the above approaches, it was discarded from the review for that risk factor. We generated a pooled odds ratio with 95% CI for the risk factors using the DerSimonian-Laird [79] random effects method of meta-analysis. Statistical significance was considered with a  $p$  value  $<0.05$ . Heterogeneity between studies was analyzed using Cochran's  $Q$  statistic, its  $p$  value and Higgins and Thompson  $I^2$  statistic [80]. We considered an  $I^2$  value of less than 30% as indicating low heterogeneity, 30% to 50% as representing moderate heterogeneity, and a value between 50% and 100% as representing considerable heterogeneity. We did subgroup and meta-regression analysis for the risk factors which showed considerable heterogeneity ( $>75\%$ ).

### 3. Results

**3.1. General Study Characteristics.** Our search strategy identified 1,202 records from a database search for potential inclusion in the review. After the screening process, a total of 25 studies met the eligibility criteria and were selected for the systematic review and meta-analysis (Figure 2). These included studies involved 845,096 participants (aged 11-86 years), 48.3% of whom were women. Studies were published from 2010 to 2022 and were from 19 different countries: 11 from the USA; 3 from France; 2 from each of Bangladesh, China, and Poland; and 1 from each of Mexico, Russia, South Africa, Ghana, Denmark, India, England, Scotland, Finland, Spain, Australia, Brazil, and Germany (Figure 3). The median sample size was 3,921, ranging from 130 to 444,297 participants. The majority of the studies were conducted on the general population ( $n = 23$ , 92%) and a few on psychiatric inpatients ( $n = 2$ , 8%) as shown in Figure 4. 21 of the studies (84%) included both male and female participants. The most frequent study design was cross-sectional ( $n = 15$ , 60%); 5 studies (33.3%) were case-control, 3 were prospective cohort (12%), and 2 were retrospective cohort (8%). The most common suicidality type (outcome) assessed by studies was suicide attempt ( $n = 15$ , 41.7%) followed by suicidal ideation ( $n = 12$ ), suicide plan ( $n = 3$ ), suicide risk ( $n = 3$ ), and suicide death ( $n = 3$ ). 12 studies assessed a 12-month period of suicidality, 6 studies assessed a period of 2-4 years, 1 longitudinal study assessed 13 years, and 6 studies did not report the period assessed. Characteristics of the included studies can be found in Appendix B (available here).

In terms of risk factors, 19 studies assessed comorbid disorders and behavior, 12 studies assessed socio-demographic factors, 11 studies assessed negative life experiences, 9 studies assessed social and familial characteristics, and 6 studies assessed family and personal psychiatry histories. In the comorbid disorders and behavior category, 10 studies assessed depression, 7 studies assessed any diagnosed mental disorder, 6 studies assessed alcohol use problems, 6

studies assessed psychoactive substance use disorders, 4 studies assessed anxiety disorders, 4 studies assessed cigarette smoking, 3 studies assessed behavioral problems, 3 studies assessed multiple chronic health conditions, 3 studies assessed physical illness or disability, 2 studies assessed bipolar disorder, 2 studies assessed borderline personality disorder, 2 studies assessed impulsivity, and 2 studies assessed posttraumatic stress disorder. Concerning socio-demographic factors, 7 studies assessed gender, 4 studies assessed education level, 4 studies assessed family income, and 3 studies assessed marital status. Concerning negative life events, 8 studies assessed adverse life events, 3 studies assessed sexual trauma, 3 studies assessed physical trauma, 2 studies assessed exposure to domestic violence, and 2 studies assessed school environment. Concerning social and familial characteristics, 4 studies assessed loneliness or isolation, 3 studies assessed social support, 3 studies assessed family functioning, and 2 studies assessed parents' relationship status. Concerning family and personal psychiatry history, 3 studies assessed family suicide history, 3 studies assessed an individual's previous suicide attempt, 2 studies assessed peer suicide attempt, and 2 studies assessed family mental illness history.

**3.2. Meta-Analysis.** In this section, we address RQ2: "How are the different risk factors statistically associated with suicide? What positive or negative relationships exist between different risk factors and suicide?" There were large variations in the sample sizes of studies in the meta-analysis. All static and dynamic risk factors reported in more than one study are presented in Table 2. RQ1: "What are the different risk factors for suicide?" is also answered in Table 2. When considering all types of suicidalities and all time periods together, certain risk factors had significant odds ratio (OR) within the risk factor domains. Comorbid disorders and behavior domains showed strongest association with suicide (OR = 1.47, 95% CI [1.28-1.67]; Table 2) followed by the negative life experiences domain (OR = 1.26, CI [0.85-1.68]). The least association was observed in social and familial characteristics with suicide (OR = 0.45, CI [0.3-0.61]). Heterogeneity for all the five risk factor domains ranged from 0 to 99.7% (i.e., moderate to substantial heterogeneity was observed between the studies).

**3.2.1. Comorbid Disorders and Behavior.** In the domain of comorbid disorders and behavior, the four strongest risk factors were any diagnosed mental disorder (OR = 2.7, CI [0.6-4.81]), multiple chronic health conditions (OR = 1.95, CI [1.1-2.81]), bipolar disorder (OR = 1.85, CI [0.51-3.19]), and depression (OR = 1.42, CI [0.99-1.85]). A forest plot showing the odds ratio of risk factors with suicide in this domain can be found in Appendix C (available here). Other risk factors which showed positive association were psychoactive substance use disorder (OR = 1.39, CI [0.53-2.25]), impulsivity (OR = 1.34, CI [0.11-2.57]), and alcohol use problem (OR = 1.12, CI [0.29-1.96]). Borderline personality disorder showed an increased risk but a nonsignificant association with suicide (OR = 1.55, CI [-0.92-4.02]). There was no clear association with anxiety disorder (OR = 0.97, CI

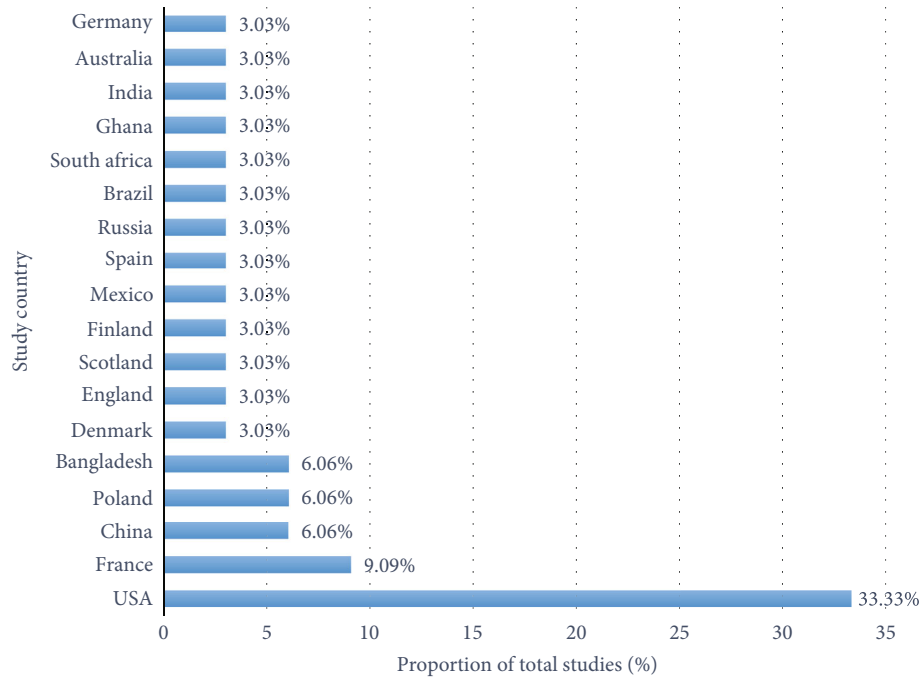


FIGURE 3: Trend of studies on risk factors for suicide by study country. About one-third of the studies (33.33%) were conducted in the USA.

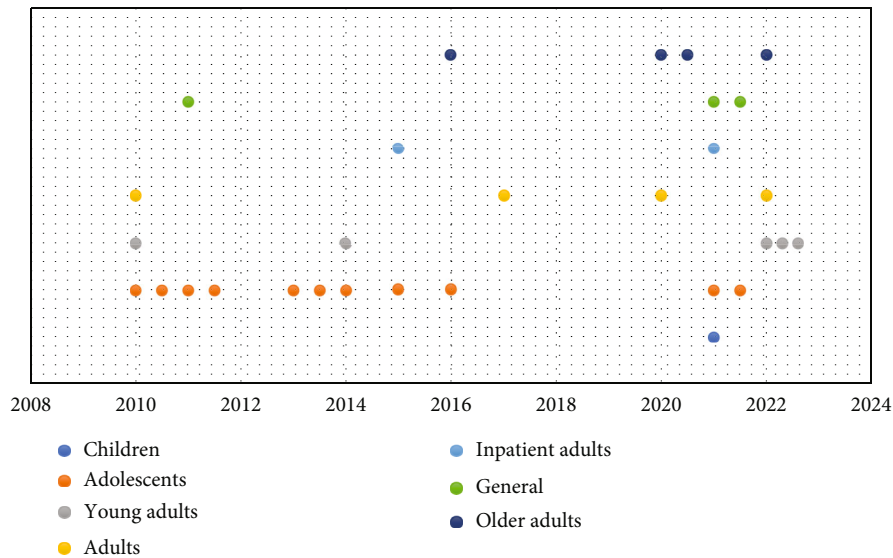


FIGURE 4: Studies on risk factors for suicide by the target population and year of publication. About 44% ( $N = 11$ ) of the studies were conducted on adolescents. The least proportion of studies was based on children (27%,  $N = 3$ ). Since 2020, all different target populations were studied to determine the risk factors for suicide in respective age group.

[-0.08-2.03]), behavioral problems (OR = 1.01, CI [-0.54-2.56]), physical illness or disability (OR = 0.87, CI [-0.38-2.11]), cigarette smoking (OR = 1.16, CI [0.83-1.49],  $p = 0.057$ ), and posttraumatic stress disorder (OR = 1.09, CI [0.79-1.39],  $p = 0.610$ ).

**3.2.2. Family and Personal Psychiatric History.** With respect to the domain of family and personal psychiatric history (Figure 5), past suicide attempt was most strongly associated with suicide (OR = 1.41, CI [0.33-2.48]). A family history of suicide presented an increased risk of suicide (OR = 0.98, CI

[0.61-1.35]). Family mental illness history showed an increased risk but a statistically insignificant association with suicide (OR = 1.33, CI [0.66-2.00],  $p = 0.062$ ). Exposure to peer-suicide attempts presented a partially positive but statistically insignificant association with suicide (OR = 0.67, CI [0.46-0.88],  $p = 0.953$ ).

**3.2.3. Negative Life Experiences.** In the domain, negative life experiences (Figure 6), we found adverse life events (OR = 1.65, CI [0.82-2.48]) to be strongly positively associated with suicide followed by sexual trauma (OR = 1.00, CI

TABLE 2: Risk factors associated with suicide (ordered by domain) and their calculated odds ratios.

|                                       | Number of studies | Pooled odds ratio (95% CI) | <i>p</i> | Heterogeneity (I2) |
|---------------------------------------|-------------------|----------------------------|----------|--------------------|
| Comorbid disorders & behavior         | 54                | 1.47 (1.28–1.67)           | 0.00     | 99.7%              |
| Any diagnosed mental disorder         | 7                 | <b>2.7 (0.60–4.81)</b>     | 0.00     | 99.5%              |
| Alcohol use problem                   | 6                 | 1.12 (0.29–1.96)           | 0.00     | 98.3%              |
| Anxiety disorder                      | 4                 | 0.97 (-0.08–2.03)          | 0.00     | 98.0%              |
| Behavioral problems                   | 3                 | 1.01 (-0.54–2.56)          | 0.00     | 99.5%              |
| Bipolar disorder                      | 2                 | 1.85 (0.51–3.19)           | 0.010    | 84.7%              |
| Borderline personality disorder       | 2                 | 1.55 (-0.92–4.02)          | 0.00     | 99.7%              |
| Cigarette smoking                     | 4                 | 1.16 (0.83–1.49)           | 0.057    | 60.1%              |
| Depression                            | 10                | 1.42 (0.99–1.85)           | 0.00     | 99.7%              |
| Impulsivity                           | 2                 | 1.34 (0.11–2.57)           | 0.009    | 85.4%              |
| Multiple chronic health conditions    | 3                 | 1.95 (1.10–2.81)           | 0.001    | 84.7%              |
| Physical illness or disability        | 3                 | 0.87 (-0.38–2.11)          | 0.00     | 97.6%              |
| Posttraumatic stress disorder         | 2                 | 1.09 (0.79–1.39)           | 0.610    | 0.0%               |
| Psychoactive substance use disorder   | 6                 | 1.39 (0.53–2.25)           | 0.00     | 97.3%              |
| Family & personal psychiatric history | 10                | 1.12 (0.73–1.52)           | 0.00     | 95.5%              |
| Exposure to peer suicide attempt      | 2                 | 0.67 (0.46–0.88)           | 0.953    | 0.0%               |
| Family history of suicide             | 3                 | 0.98 (0.61–1.35)           | 0.013    | 77.0%              |
| Family mental illness history         | 2                 | 1.33 (0.66–2.00)           | 0.062    | 71.2%              |
| Past suicide attempt                  | 3                 | <b>1.41 (0.33–2.48)</b>    | 0.00     | 98.6%              |
| Negative life experiences             | 16                | 1.26 (0.85–1.68)           | 0.00     | 95.6%              |
| Adverse life events                   | 8                 | <b>1.65 (0.82–2.48)</b>    | 0.00     | 97.3%              |
| Exposure to domestic violence         | 2                 | 0.97 (-0.16–2.09)          | 0.03     | 77.8%              |
| Physical trauma                       | 3                 | 0.53 (0.13–0.94)           | 0.003    | 82.3%              |
| Sexual trauma                         | 3                 | 1.00 (0.21–1.79)           | 0.00     | 89.7%              |
| Social & familial characteristics     | 12                | 0.45 (0.30–0.61)           | 0.00     | 91.9%              |
| Single/widowed/separated parents      | 2                 | 0.84 (0.52–1.16)           | 0.971    | 0.0%               |
| Low social support                    | 3                 | 1.32 (-0.2–2.85)           | 0.00     | 93.0%              |
| Loneliness or high isolation          | 4                 | <b>0.21 (0.01–0.40)</b>    | 0.00     | 94.9%              |
| Poor family functioning               | 3                 | 0.82 (0.43–1.22)           | 0.145    | 48.1%              |
| Sociodemographic characteristics      | 18                | 0.77 (0.57–0.97)           | 0.00     | 87.6%              |
| Female                                | 7                 | 0.76 (0.52–1.00)           | 0.00     | 79.2%              |
| Low education level                   | 4                 | <b>1.00 (0.22–1.79)</b>    | 0.00     | 91.3%              |
| Low family income                     | 4                 | 0.63 (0.25–1.01)           | 0.078    | 56.1%              |
| Unmarried                             | 3                 | 0.75 (0.25–1.25)           | 0.057    | 65.0%              |

[0.21–1.79]). Physical trauma showed an increased risk of suicide (OR = 0.53, CI [0.13–0.94]). Exposure to domestic violence (OR = 0.97, CI [-0.16–2.09]) did not reflect any clear association with suicide.

**3.2.4. Social and Familial Characteristics.** The domain, social and familial characteristics (Figure 7), showed the least positive association compared to other risk factor domains. Loneliness or high isolation (OR = 0.21, CI [0.01–0.40]) showed a mild positive association with suicide. Low social support (OR = 1.32, CI [-0.2–2.85]) was found to increase risk, but the association was statistically nonsignificant to suicide. No clear association was observed between single/widowed/separated parents (OR = 0.84, CI [0.52–1.16],  $p = 0.971$ ) and poor family functioning (OR = 0.82, CI [0.43–1.22],  $p = 0.145$ ).

**3.2.5. Sociodemographic Characteristics.** In the socio-demographic characteristics domain (Figure 8), we found low education level (OR = 1.00, CI [0.22–1.79]) and being a female (OR = 0.76, CI [0.52–1.00]) to be positively associated with suicide. There were no significant relationships between being unmarried (OR = 0.75, CI [0.25–1.25],  $p = 0.057$ ) or low family income (OR = 0.63, CI [0.25–1.01],  $p = 0.078$ ) and suicide.

In this section, we address RQ3: “Which risk factor(s) are most strongly associated with suicide?” The leading risk factors from each domain (Table 3) were any diagnosed mental disorder, adverse life events (like food deprivation, job or financial problem, and campus ragging), past suicide attempt (by the individual), low education level, and loneliness or high isolation. Other prominent risk factors (Table 2) that were found to have significant positive



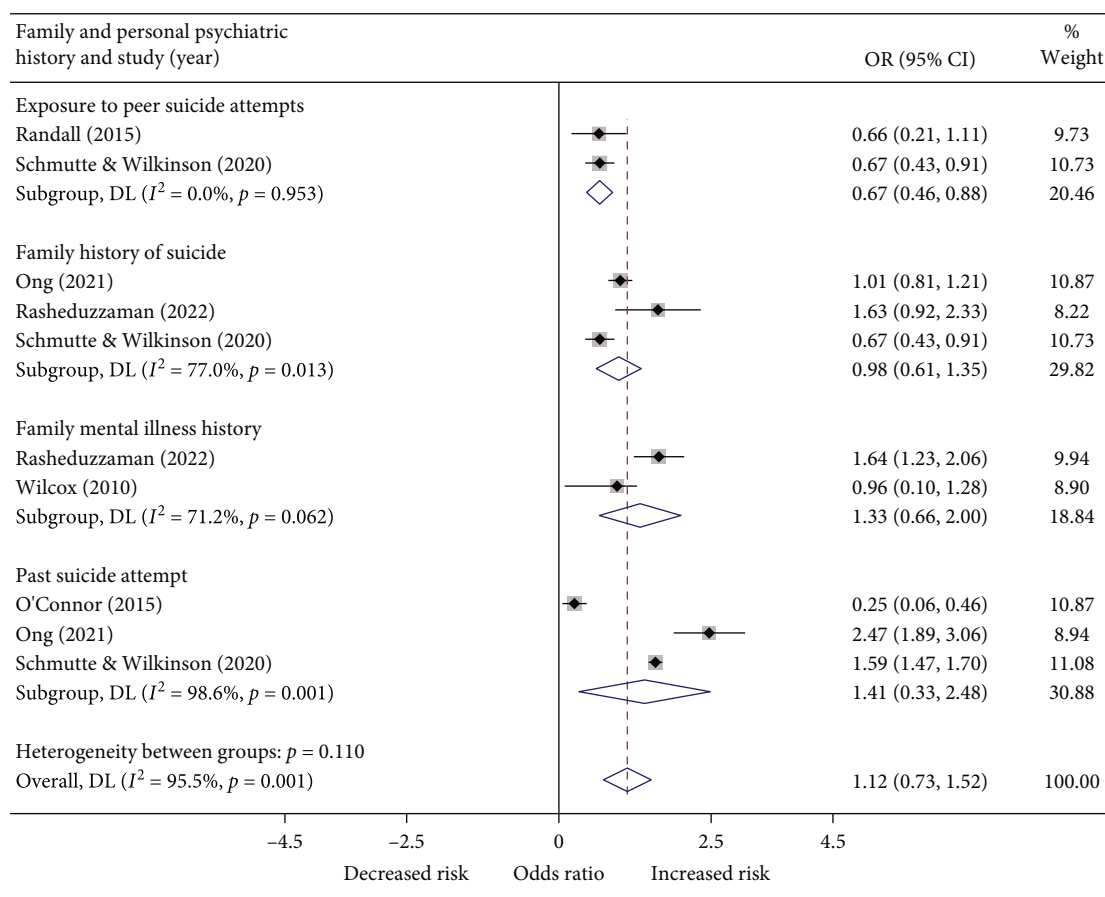


FIGURE 5: Family and Personal psychiatric history as risk factors for suicide. Studies are identified from the first author and publication year. The size of grey boxes represents the weight attributed to each study. Weights are from the random effects model. The diamonds denote the pooled summary effect size and CI's (95% confidence interval). OR = Odds ratio. Risk factors in the domain family and personal psychiatric history, that are most strongly associated with suicide are family history of suicide and past suicide attempt.

associations were bipolar disorder, depression, multiple chronic health conditions, family history of suicide, sexual trauma, and being female.

#### 4. Discussion

This systematic review and meta-analysis were based on 77,890 suicides from 25 studies in 19 countries and synthesized risk factors for suicide by comorbid disorders and behavior, family and personal psychiatric history, negative life experiences, social and familial, and sociodemographic domains. Among the risk factor domains, the strongest association with suicide was with comorbid disorders and behavior followed by negative life experiences. The least associated risk factor domain with suicide was social and familial characteristics, which was intriguing. The five strongest factors associated with suicide from each domain (Table 3) were any diagnosed mental disorder, adverse life events, past suicide attempt, low education level, and loneliness or high isolation. Other prominent risk factors (Table 2) found to have significant positive associations were bipolar disorder, depression, multiple chronic health conditions, family history of suicide, sexual trauma, and being female. This work provides new evidence in three ways. First, it adds precision

to the associations reported in previous meta-analyses [10, 14, 57, 58], which is necessary for modifiable risk factors that can facilitate the development of preventive interventions. Second, it provides new quantitative data on multiple risk factors relating to suicide, namely, bipolar disorder, borderline personality disorder, impulsivity, multiple chronic health conditions, physical illness or disability, exposure to peer-suicide attempt, family history of suicide, family mental illness history, physical trauma, sexual trauma, and loneliness or high isolation that were not identified in previous meta-analyses. These risk factors were stated in a previous meta-analysis [57], but no quantitative associations were measured with suicide. Third, for some of the risk factors for which there was uncertainty, this work further clarified the direction of the effects.

In our review, we found that the majority of the studies (44%) were conducted in the US. This reflects that research on suicide and its risk factors is heavily inclined towards the western context. The WHO estimates that about 77% of global suicides occur in low- and middle-income countries [81]. To tackle suicide globally, more research is needed in low- and middle-income countries as opposed to currently overrepresented developed geographies. Some studies (12%) assessed "suicide risk" as the outcome which is

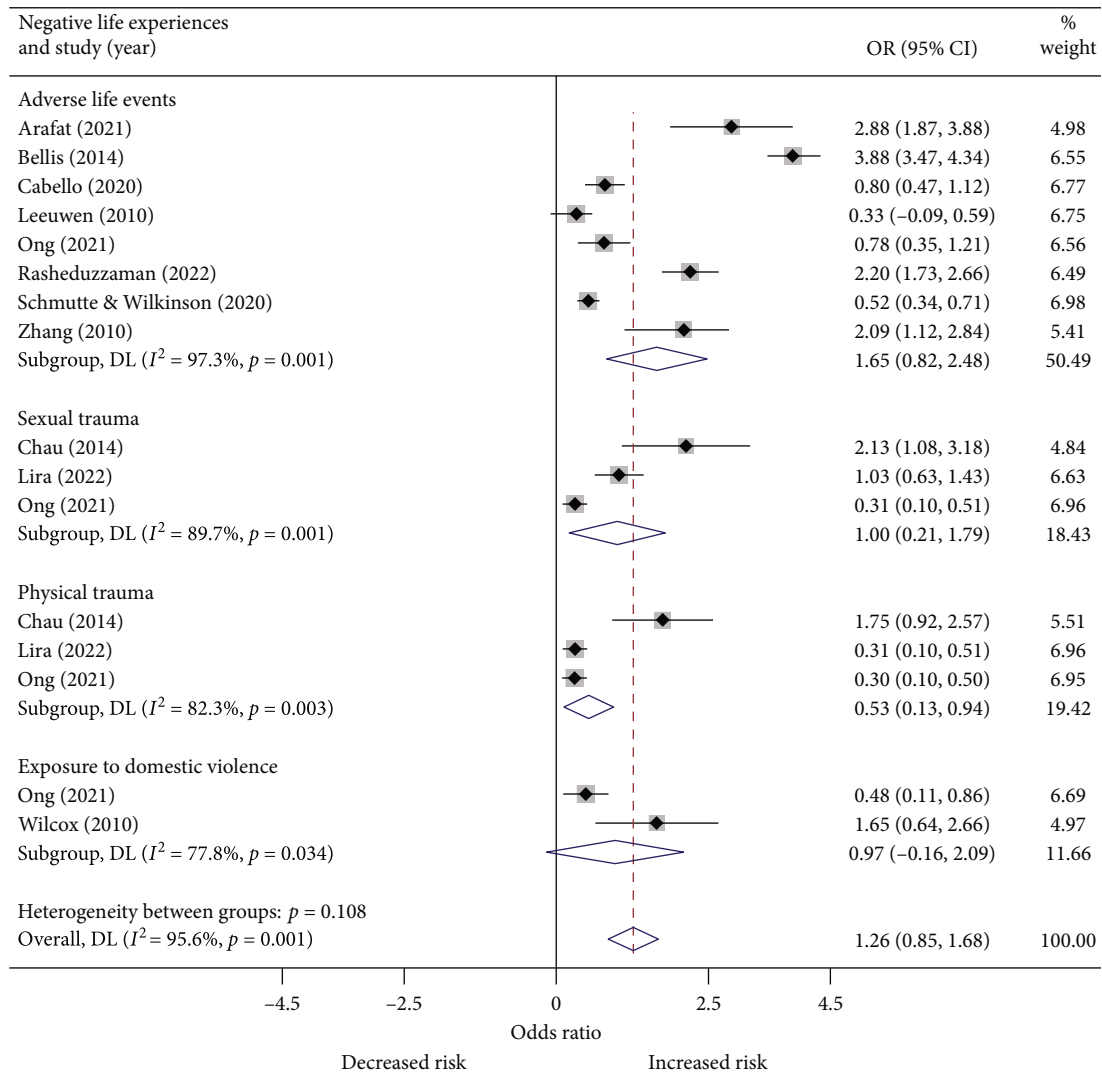


FIGURE 6: Negative life experiences as risk factors for suicide. Risk factors in this domain that are most strongly associated with suicide are adverse life events and sexual trauma.

ambiguous since suicidality is a complex phenomenon with stages along a continuum [5]. A clearly defined suicidality outcome in studies will help provide prevention interventions at the earliest and appropriate stage of suicidality. About a quarter of the studies (24%) did not report the period of suicidality assessed. This is problematic as a very short duration of assessment period will not lead to significant results, and lack of this information can lead to exclusion of studies.

Additionally, about 44% of the studies were conducted on adolescents and adults, each of which supports the need for research on this age group as the WHO estimates that over half of all deaths by suicide (58%) occur before 50 years of age [1]. The risk factor of comorbid disorder and behavior was found to have the strongest association with suicide. This implies that health and affective disorders significantly increase suicide risk, and treatment of comorbid health conditions should be considered first and foremost in preventive policies for suicide. Health care services need to be universally accessible, adequately resourced, and directly linked to

suicide prevention interventions. The second most significantly associated risk factor domain was negative life events. Adverse life situations like financial, job, food-related problem, and trauma should not be overlooked. Modifiable risk factors like bullying and trauma (sexual, physical, and emotional) can be addressed to some extent by using long-term psychosocial interventions like cognitive behavioral therapy (CBT) [82], acceptance and commitment therapy (ACT) [83], collaborative assessment, and interpersonal psychotherapy [8]. Governmental policies should be developed around food assistance and financial and job security for at-risk populations. Family plays a major role in an individual's course of life, and surprisingly, we found that the social and familial risk factor domain was the least associated with suicide. This could be explained as the effect of social and familial characteristics like loneliness or high isolation and low social support as opposed to other risk factor domains would have been less.

In comorbid disorders and behavior risk factors, we found strong associations with any diagnosed mental

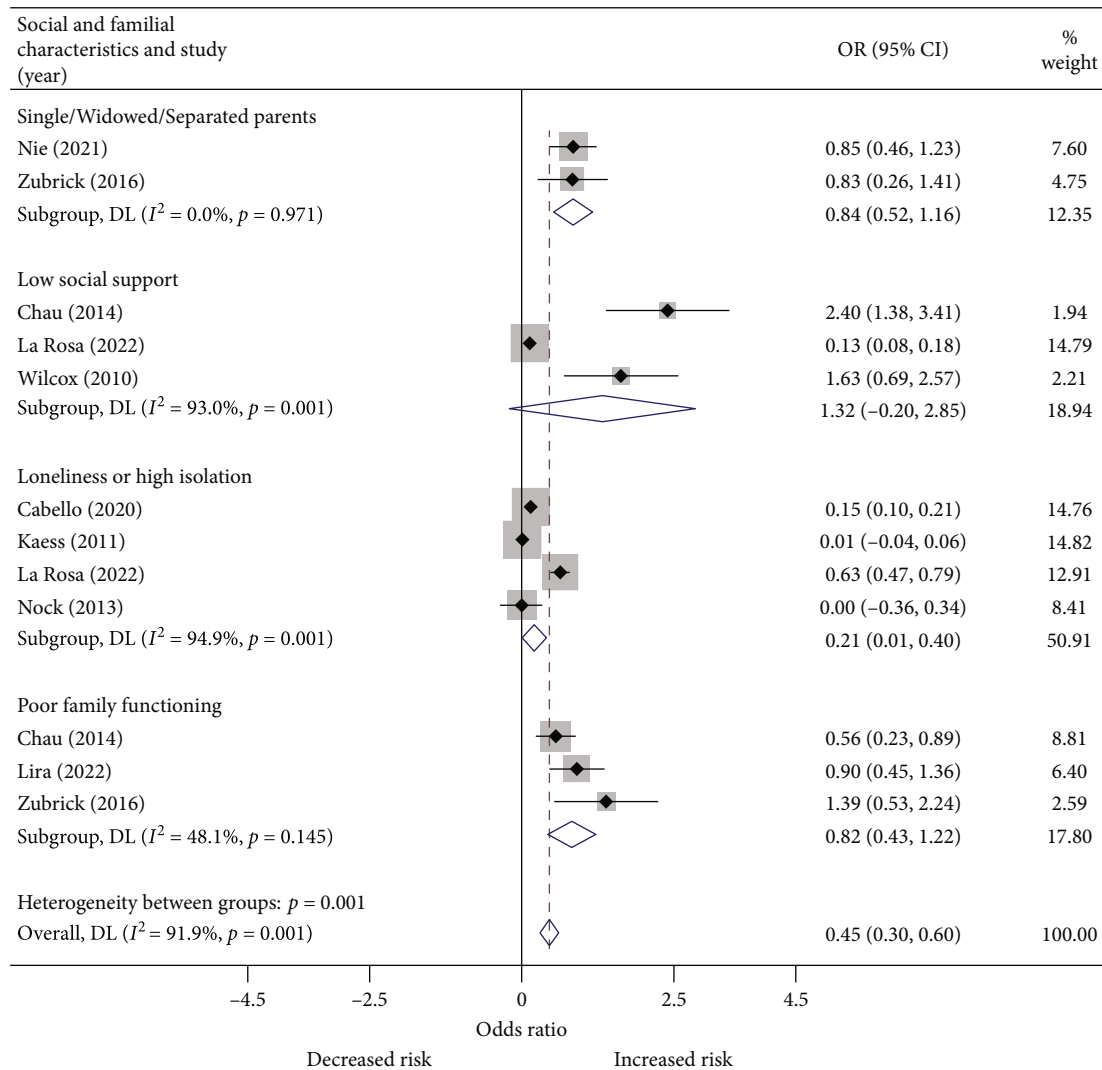


FIGURE 7: Social and familial characteristics as risk factors for suicide. Risk factor in this domain that is most strongly associated with suicide is loneliness or high isolation.

disorder, multiple chronic health conditions, bipolar disorder, and depression. Mental health diagnosis is thus crucial to prevent larger and gradually developed conditions like suicide. Adequate training for assessment and easy access to mental health services for the general population should be considered. Individuals at-risk of suicide should be promptly assessed by mental health professionals. Unmet health needs (physical or mental) and delays in preventive care should be primarily resolved as part of preventive interventions. We also found other behavioral conditions like psychoactive substance use disorder, impulsivity, and alcohol use problem to be positively linked to suicide. Access to psychoactive substances should be regulated by preventive policies. Alcohol and psychoactive substance addiction-related awareness should be instilled in individuals from an early age. Impulsive behavioral traits are usually reflected from an early age. Intervention programs that involve psychotherapy should be developed and included in the assessment of adolescents in their natural environments (e.g., schools and sports centres). Adequate access to such

resources for parents and periodic assessment reminders would help parents, and teachers identify at-risk adolescents.

In the domain of family and personal psychiatry history, past suicide attempt was found to be a strong predictor followed by a family history of suicide. Psychiatric patients with a history of suicide attempts should be provided with treatment via preventive psychotherapy and other interventions as they are at high risk of suicide in the future. Family suicide history is also reflective of suicide risk, and family members of a suicide-deceased individual should have access to psychotherapy, special care, and social support to prevent future suicides.

In the domain of negative life experiences, adverse life events and sexual trauma were strongly associated with suicide. Survivors of sexual trauma should be provided with health care services (both physical and mental health) to facilitate their process of recovery at a minimum cost. In the domain of social and familial characteristics, unexpectedly, loneliness or high isolation was found to have a mild positive association with suicide. We hypothesized that

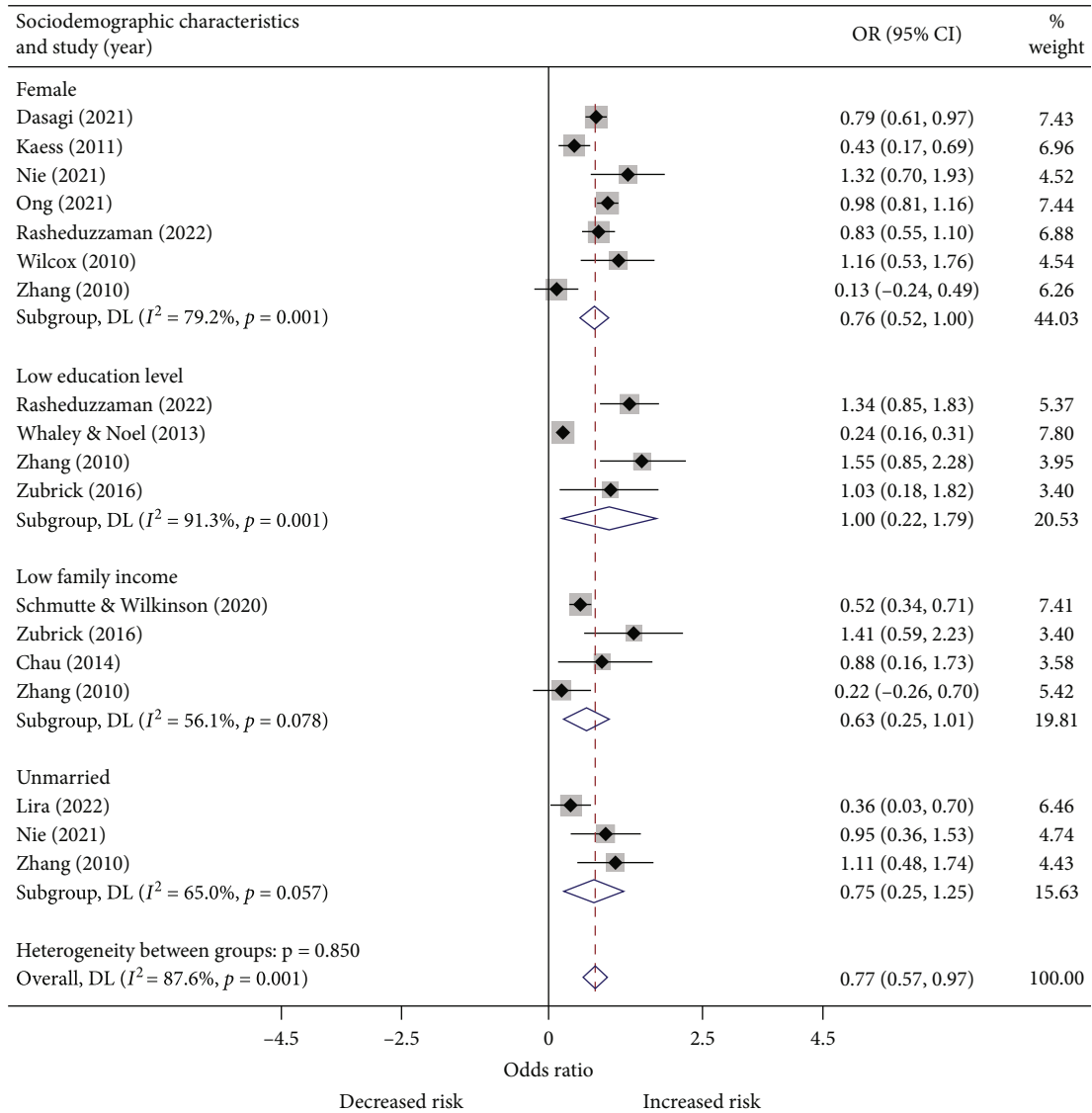


FIGURE 8: Sociodemographic characteristics as risk factors for suicide. Risk factors in this domain that are most strongly associated with suicide are being female and low education level.

TABLE 3: Leading risk factors for suicide from each domain.

|                               | OR (95% CI)      |
|-------------------------------|------------------|
| Any diagnosed mental disorder | 2.7 (0.60–4.81)  |
| Adverse life events           | 1.65 (0.82–2.48) |
| Past suicide attempt          | 1.41 (0.33–2.48) |
| Low education level           | 1.00 (0.22–1.79) |
| Loneliness or high isolation  | 0.21 (0.01–0.40) |

loneliness or high isolation would cause the individual to resort inwards and would catalyse the occurrence of suicidal ideas. The mild association with suicide is still statistically significant enough for us to take it into consideration when developing preventive interventions. In the domain of socio-demographic characteristics, both low education level and being female were strongly associated with suicide. Access to education for the general population, especially in low

and middle-income countries which report half of all global suicides, would be beneficial. Female individuals in at-risk of suicide population groups should be provided with easier means to access preventive interventions.

We present a hierarchical model of risk factor domains of suicide (Figure 9) that provides a comprehensive view of different risk factor domains and their interrelationships. This framework suggests that there are two primary parameters: (1) the individual or self and (2) the world, which forms the basis of this model. The sociodemographic factors like age, gender, and education level, as well as comorbid disorders and behavioral factors like affective disorders, are intrinsic to an individual or the self. Social connections which are a part of the world consist of the individual’s family and society. Social and familial factors like social support, family functioning, and isolation are formed by the interplay of family and society. Negative life experiences like bullying, financial or job stress, domestic violence, and sexual trauma

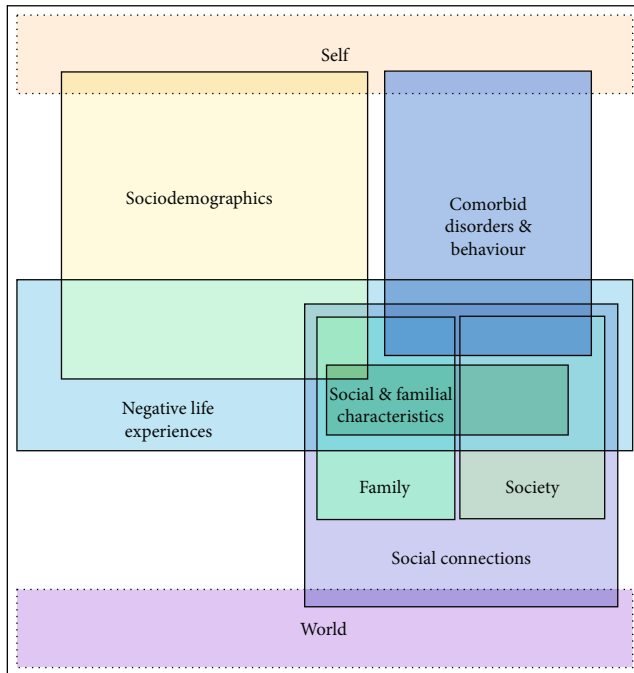


FIGURE 9: Hierarchical taxonomy of risk factor domains of suicide showing how they are interlinked.

are created by the amalgamation of sociodemographic, comorbid disorders and behavior, and social connections. Comorbid disorders and behavior, family, and society together form the family and personal psychiatry history risk factors. Each of the risk factor domains links to one or more other risk factor domains and is formed as a result of the fundamental parameters: self, world, family, and society.

An example would be a boy who is experiencing suicidal thoughts and ideation. Intrinsic traits form his sense of “self,” and extrinsic conditions comprise his sense of the “world.” His sociodemographic variables like age, education level, and place of birth contribute indirectly to his suicide risk. His comorbid disorder and behavioral factors, like the presence of affective disorders, alcohol use problem, and anxiety disorder, are formed by the interplay of intrinsic traits (from the self) and negative life experiences that he undergoes like exposure to domestic violence, bullying, sexual trauma, and the influence of family and society. Social and familial variables like low social support, poor family functioning, and loneliness or high isolation are formed by the combination of family and society that he belongs to. Joiner’s interpersonal theory of suicide states that a sense of low belongingness or social isolation (which is a social and familial characteristic) when held simultaneously with perceived burdensomeness, for long enough, can lead to the desire for death [84]. His sense of the world consists of social connections which are comprised of family and society. Each of the variables from the different risk factor domains is a contributing risk factor for suicide. To understand the cause of suicide, we must look at each of the risk factor domains and how they contribute together to develop the complex suicidal behavior in an individual.

Ecological models of suicide propose a framework for understanding dynamic interrelations among various individuals, environmental factors, and suicidal behaviors [85]. For example, Zayas’ eco-developmental model of Latina suicide attempts [83] suggests that suicidal behavior in Latina adolescents emerges at the intersection of sociocultural (e.g., female rearing norms), familial (e.g., conflict), and developmental (e.g., adolescent autonomy) dynamics. This is similar to our framework which identifies additional dynamics at play. Another model is the integrated motivational-volitional (IMV) model of suicidal behavior [84] which states that an individual’s environment and life events are background factors and triggering events for suicidal behavior. One more model is the unified theoretical model of suicidal behavior [85] which consists of events and psychological and motivational moderators as factors leading to suicidal behavior. All these models bring attention to the role of contextual factors in shaping suicidal behaviors.

Overall, this work lessens the challenges faced by researchers as they try to understand the problem of suicide and what causes it. It provides an overview of quantitative associations between a range of risk factors and suicide which can be incorporated in the development of suicide prevention technologies. The findings from our meta-analysis and systematic review have revealed several possible areas for exploration in the field of suicide research. In the next section, we offer several open research questions that other researchers can further investigate.

**4.1. Research Opportunities for Suicide Detection and Prevention.** Based on the results of our review, we present a set of open research questions (Table 4) for researchers in the field of suicide detection and prevention to add to their research agenda. These ideas can be explored to develop preventive interventions that are effective and help address the problem of suicide.

Apart from the open research questions, the risk factor relationships derived in our work also address RQ4: “What are some considerations derived from the risk factor-suicide relationships that can be used to develop effective suicide prevention technologies?” In the following section we present recommendations for developing more effective suicide prevention technologies.

**4.2. Considerations for Developing Suicide Prevention Technologies.** We present some considerations that can help application developers create better technologies for suicide prevention:

- (1) Preventive technological interventions for suicide should primarily target the key risk factor domain of comorbid disorders and behavior. Application developers should explore the use of sensor data to assess the individual for comorbid conditions
- (2) Interventions should connect data from medical diagnosis to the application to provide an accurate diagnosis that includes data from supporting facilities that the individual is taking

TABLE 4: Open research questions for research on suicidality and preventive interventions.

| Concept                 | Possible research questions   |
|-------------------------|---|
| Demographics            | What are the differences in prominent risk factors for suicide based on countries' economic progress? (high-income versus low- and middle-income)                           |
|                         | What are the differences in risk factors for suicide depending on the environment (home, school, and work)?   |
|                         | How do ethnicity, race, sexual orientation, gender identity, and refugee status relate to suicide?  |
| Stages of suicidality   | Are risk factors for suicide dependent on the stage of suicide (suicidal ideation, plan, attempt, and death)?   |
|                         | How can we connect preventive interventions to stages of suicidality?   |
| Society and family      | How can familial factors like parental marital status, loneliness, family functioning, and family conflict be addressed and linked to preventive interventions for suicide? |
| Life adversities        | How can adverse life conditions be addressed and connected to preventive interventions for suicide?   |
|                         | How do childhood and adulthood adversities impact the stages of suicidality and respective preventive strategies?   |
| Preventive technologies | What technological mediums (e.g., mobile, web, AR, VR, games, robot, smartwatch, or audio-visual technology) can be explored for developing preventive interventions?       |
|                         | How can internet communities (e.g., subreddits and twitter spaces) be utilized to create preventive strategies?   |
|                         | How can persuasive technologies be used to develop technologies for preventive intervention?  |
|                         | What role will the stage of suicidality and time period play in the development of tailored persuasive interventions?   |

- (3) Adverse life events like food deprivation, job or financial problem, and campus ragging should also be assessed by applications. This can be done by using self-reported standard scales or by accessing governmental data wherever necessary within the application
- (4) Application developers should clearly define the stage of suicidality (like suicidal ideation, plan, and attempt) that the preventive intervention is targeting and adopt prevention strategies in accordance with the gravity of the suicidality stage
- (5) As health and affective disorders significantly increase suicide risk, treatment of comorbid health conditions should be considered necessary in preventive interventions. Health care services should be directly accessible in such applications. Application developers can explore how preventive interventions like cognitive behavioral therapy (CBT), acceptance and commitment therapy (ACT), and interpersonal psychotherapy can be administered via technology
- (6) Internet communities like subreddits can be integrated within preventive applications for peer support
- (7) Persuasive strategies can be implemented to make the application persuasive and tailored to the individual's key risk factor(s)

*4.3. Challenges of Researching This Field.* Some of the studies did not report the period of suicidality assessed which brings the authenticity of their results into question. Some studies defined the outcome of assessment ambiguously (e.g., suicide risk). This was problematic as suicide risk is present

during both suicidal ideation and suicide plan stage. In such studies, it becomes difficult to clearly outline which stage of suicidality the authors are targeting. With the lack of this information, it is difficult to lay out preventive interventions at the appropriate stage of suicidality.

*4.4. Strengths and Limitations.* One of the strengths of this work is the large number of suicide cases ( $n = 77,890$ ) that were considered. Secondly, this quantitative synthesis provides new data on multiple risk factors relating to suicide (like bipolar disorder, borderline personality disorder, impulsivity, multiple chronic health conditions, physical illness or disability, exposure to peer-suicide attempt, family history of suicide, family mental illness history, physical trauma, sexual trauma, and loneliness or high isolation) that were previously unavailable. Thirdly, this work explores many domains of risk factors and identifies how they are linked to each other. Additionally, leading risk factors are derived from each of the domains which have the strongest associations with suicide. Finally, this work fits the leading risk factors identified into an existing framework of the world and presents a new framework to understand the problem of suicide and its causes.

Although we found many interesting results, some limitations of this work should be taken into consideration. The effect of the large variation in sample sizes in studies is unknown. Suicide and its related outcomes were defined in a varied manner across the studies reviewed. It is possible that these discrepancies are responsible for the substantial heterogeneity observed in our work. Another limitation is that the interaction between risk and protective factors of suicide has not been examined. The effect of such interactions on the results is unknown and could contribute to some of the unexpected results. We considered all types of suicidalities together for our meta-analysis. Future work

can explore the differences in risk factors for different stages of suicidality independently. The overall pooled analyses contained substantial heterogeneity and could be because of location, time period of study, and characteristics of the population. Future work should also address the measurement of suicide outcomes and the effect of variation in sample sizes. Additionally, risk factors should be studied in low- and middle-income countries to derive variations (if any). Since about half of our studies were based on the western context, it is difficult to generalize our results in the global context. Future work can explore the possibility of using tailored persuasive strategies for preventive interventions.

## 5. Conclusion

In conclusion, we discussed a variety of comorbid disorders and behavior, negative life experiences, family and personal psychiatric history, sociodemographic, and social and familial risk factors for suicide. Our work identifies prominent risk factors, which could be modified and used to enhance suicide intervention and prevention programs. The results indicate that comorbid disorders and behavior are most strongly associated with suicide. The five strongest factors associated with suicide are any diagnosed mental disorder, adverse life events, past suicide attempt, low education level, and loneliness or high isolation. We presented a new hierarchical model of risk factors of suicide that advances our understanding of suicide and its causes. We also formulated open research questions and considerations for developing suicide prevention technologies. These findings extend our understanding of suicide and its causes, especially the leading causes, and will enable researchers and practitioners to develop personalized technological interventions that target modifiable risk factors at an early onset in the future.

## Data Availability

The data about databases reviewed, search strings used for the systematic review, characteristics of included studies, and forest plot of comorbid disorders and behavior as risk factors for suicide are included within the supplementary files.

## Ethical Approval

This is a review paper, which did not involve human subjects in any way; hence, this declaration is not applicable.

## Conflicts of Interest

The authors declare that they have no competing financial or nonfinancial interests.

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## Supplementary Materials

*Supplementary 1.* Appendix A. Databases reviewed and search strings used for the systematic review.

*Supplementary 2.* Appendix B. Characteristics of included studies.

*Supplementary 3.* Appendix C. Forest plot showing odds ratio of risk factors with suicide in the comorbid disorders and behavior domain can be found here.

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