Universal interventions for suicide prevention in high-income Organisation for Economic Co-operation and Development (OECD) member countries: a systematic review

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ABSTRACT

Introduction To examine the effectiveness of universal suicide prevention interventions on reducing suicide mortality in high-income Organisation for Economic Co-operation and Development (OECD) member countries.

Methods We implemented a comprehensive search strategy across three electronic databases: MEDLINE (Ovid), PsycINFO (Ovid) and Embase (Ovid). All studies using time-series, retrospective, prospective, pre–post or cross-sectional study designs were included. Studies were required to examine suicide mortality as the outcome of interest. To help organise the results, studies were grouped into six broad categories of universal interventions consistent with the World Health Organization (WHO) Comprehensive Mental Health Action Plan. A narrative synthesis of results was used to describe the findings.

Results Of the 15 641 studies identified through the search strategy, 100 studies were eligible in the following categories: law and regulation reforms (n=66), physical barriers (n=13), community-based interventions (n=9), communication strategies (n=4), mental health policies and strategies (n=7), and access to healthcare (n=1). Overall, 100% (13/13) of the included physical barrier interventions resulted in a significant reduction in suicide mortality. Although only 70% (46/66) of the law and regulation reform interventions had a significant impact on reducing suicide, they hold promise due to their extended reach. Universal suicide prevention interventions seem to be more effective at reducing suicide among males than females, identifying a need to stratify results by sex in future studies.

Conclusions These findings suggest that universal suicide prevention interventions hold promise in effectively reducing suicide mortality in high-income OECD countries.

INTRODUCTION

Suicide is a significant public health concern globally, with an estimated 800 000 people dying by suicide worldwide every year.[1] The causes of suicide are complex and result from a combination of individual, social and economic factors that vary substantially between countries. For instance, the methods used by those who die by suicide, and the risk factors that influence suicide, vary substantially between low-income and high-income countries.[2–4] For example, the most common method of suicide in South Africa is hanging followed by poisoning with pesticides and medication; however, in the USA, suicide death most commonly occurs by firearm, followed by suffocation.[3 5] As a result, interventions that work in some countries may not work in others. For this reason, it is important to look at groupings of countries with similar social and economic contexts, such as Organisation for Economic Co-operation and Development (OECD) member countries belonging to the high-income category. Rates of suicide mortality in high-income OECD countries varied substantially in 2016, from 4 deaths per 100 000 individuals in Greece to over 24.6 deaths per 100 000 people in Korea.[6] The impact of suicide mortality in high-income OECD countries are generally highest among older adults (aged >65 years), adolescents (aged 10–14 years) and males when compared with females.[1]

In 2015, the United Nations Sustainable Development Goals (SDG) were released to foster peace and prosperity for people and the planet, including targets set for 2030.[7] The SDGs included goal (#3.4) to reduce global premature mortality from non-communicable diseases by one-third; indicators for this goal include a reduction in suicide mortality rates (SDG Indicator 3.4.2).[7] Among all OECD countries, suicide mortality rates have decreased steadily, falling by close to 30% between 1990 and 2015, with pronounced declines of over 40% in countries such as Hungary, Estonia and Finland.[8] Despite these declines, no OECD country is on-track to meet the SDG goal,[9] which may reflect that current efforts do not adequately include comprehensive, multisectoral strategies to reduce suicide mortality, and that addressing social determinants of health is often overlooked in suicide prevention efforts.[10] Identifying well-designed and transferrable interventions could strengthen suicide prevention strategies among several countries and facilitate meeting the SDG target.

In 2014, World Health Organization (WHO) launched the first global Comprehensive Mental Health Action Plan, of which one goal was to reduce suicide rates worldwide through prevention initiatives.[11] Comprehensive suicide prevention strategies include universal, selective and

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indicated interventions.[12] Universal interventions are designed to reach an entire population regardless of risk, as described by Rose.[13] Whereas, selective interventions target sub-populations with potentially high risk for suicide (eg, people who have experienced trauma or abuse, or who are affected by conflict or disaster). Indicated interventions target specific individuals at greater risk (eg, people living with a mental illness, people who abuse substances, those who have previously attempted suicide).[11]

To date, most systematic reviews on suicide prevention have examined the effectiveness of context-specific interventions in school, community or healthcare settings,[14] primary care interventions,[15] psychosocial interventions,[16] pharmacological interventions,[17] technology-enhanced interventions[18] or workplace interventions.[19] Recent systematic reviews have examined universal suicide prevention interventions combined with selective and indicated interventions, which does not allow for a focused examination of universal interventions' characteristics and efficacy.[20 21] Given the demonstrated effectiveness of universal interventions to address other health problems such as universal smoking policies aimed at reducing smoking rates and alcohol access and pricing on rates of harmful alcohol use,[22 23] it is essential to examine universal suicide prevention interventions and their impact in similar contexts. Thus, this systematic review's objective was to examine the effectiveness of universal prevention interventions on reducing suicide mortality, as measured by counts or rates of suicide deaths, among high-income OECD countries.

METHODS
Protocol and registration
This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement,[24] and was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO; #CRD42018086273).

Study inclusion criteria
We followed the Population, Intervention, Comparator, Outcome framework to plan the components of our systematic review.[25]

Population
This review included studies with large populations (ie, community, city, state/province, country or region) living in one or multiple of the 33 high-income OECD countries, as categorised by the World Bank. Lithuania was excluded from this study because it was added to the OECD after the original search strategy was conducted in 2018. A full list of high-income OECD countries can be found in online supplemental file 1. No limitations were placed on the age or sex of the population.

Interventions
Candidate studies were required to have studied a universal intervention, targeted at a whole geographic population, with the intention or the impact of reducing suicide mortality as rates or counts (eg, country, state or province, or citywide).

Comparators
Because this review included studies using a range of study designs, both studies with and without comparator (control) populations, such as a neighbouring state or city where the intervention was not implemented, were included.

Outcomes
Studies were required to examine changes in suicide mortality in the presence of an intervention. Our primary outcome was the change in the number or rate of intentional self-harm (suicide) deaths, defined as deaths coded to the International Classification of Diseases (ICD) intentional self-harm codes (eg, code ICD-10: X60-X84, Y87) or determined to be due to intentional self-harm, using vital statistics or other death databases, or coroner's or medical examiner's records. Suicide death data could be expressed as counts, proportions or rates.

Study design
Cross-sectional, time series, retrospective, prospective, and pre–post study designs were included. This includes natural experiment designs, where the intervention is implemented outside of the control of the researcher.

Publication status and language
Studies were eligible if they were published in peer-reviewed journals in English or French as translation resources were limited to these two languages. We excluded non-peer-reviewed papers, theses, dissertations, government reports, conference proceedings and any other form of grey literature.

Search strategy
The search strategy was developed by a librarian experienced in systematic review searching. It was peer reviewed by a second librarian using the Peer Review of Electronic Search Strategies guideline. The searches were first conducted on 4 April 2018, across three databases: MEDLINE (Ovid), PsycINFO (Ovid) and Embase (Ovid). Date restrictions were placed on the search to include papers indexed from 1 January 1990 to 31 December 2017. An updated search was conducted on 12 February 2020 to extend the search to include articles from 1 January 2018 to 13 February 2020. The search used a combination of unique subject headings and keywords related to universal suicide prevention interventions. A filter was used to restrict articles to include only 33 high-income OECD countries. See online supplemental file 2 for the final search strategy. Additionally, studies were identified by searching the reference list of included studies and other relevant published reviews.

Study selection
All of the database records were imported into RefWorks (V.2.0; ProQuest, Ann Arbor, Michigan, USA) to organise and deduplicate records. All records were then imported into Covidence (Veritas Health Innovation, Melbourne, Australia), with a second software deduplication performed before screening. At level one screening, at least two reviewers (JJL, BO and M-CI) independently screened titles and abstracts against the inclusion criteria, with consensus needed for level two inclusion. At level two screening, full texts of each record were obtained and independently screened by at least two reviewers (JJL, M-CI and HS-K), with consensus needed for final inclusion. A third reviewer (HO and JJL) helped resolve discrepancies when agreement was not attained during level one and two screening. Reviewers were not blinded to the authors of the studies.

Data extraction
Data from all included studies were extracted into a standardised spreadsheet that was peer reviewed by coauthors and pilot tested before use. All data were extracted by one reviewer (M-CI or

HS-K) and verified by a second (HO or JJL). Disputes were resolved during research team meetings.

Extracted data included the following items: author, publication year, country, study design, estimated target population size, intervention description, intervention period (calendar years), level of intervention (national, regional, community), description of mortality outcome data, source of mortality data, intervention results (eg, preintervention and postintervention results or differences/changes in mortality), comparator details if available, method of statistical analysis and summary of findings.

Study quality assessment

The Effective Public Health Practice Project (EPHPP) Quality Assessment Tool was used to assess the quality of all included studies.[26] One reviewer (M-CI and HS-K) independently evaluated each study for biases related to sample selection, study design, confounders, blinding, data collection, withdrawals, and dropouts. Each study received a global rating of 'weak,' 'moderate' or 'strong' based on the amount of potential bias incorporated into the study methods. A second assessor (JJL and M-CI) reviewed the evaluation for accuracy, with a third reviewer (HO) consulted to resolve conflicts. The EPHPP does not allow for grading the overall quality of the evidence for each intervention category. However, we highlight the range of global ratings for studies included in each intervention category.

Narrative synthesis of results

To help organise the results, studies were grouped into six broad categories of universal interventions derived from the WHO Comprehensive Mental Health Action Plan.[11] The categories include access to healthcare (eg, suicide prevention centres), communication (eg, media reporting), community-based interventions (eg, school and community-based programmes and local suicide prevention projects/initiatives such as crisis phone lines), law and regulation reform (split into firearm laws and all other laws, such as alcohol policies, tobacco policies and access to all means, including domestic gas detoxification, catalytic converter legislation, analgesics and pesticides), mental health policies (eg, national programmes/strategies and mental health insurance policies), and physical barriers for transit and bridges (eg, bridge barriers, safety nets, blue lights on train stations, platform screen doors). Studies that included multiple interventions across several categories were included under the community-based interventions category. A narrative synthesis of results was conducted for each intervention category to describe the overall findings. The diversity of intervention types and settings within each category precluded our ability to perform a meta-analysis.

RESULTS

Figure 1 displays the PRISMA flow diagram for the literature search and screening process. A total of 15 641 records were identified through database searches and additional sources. After deduplication, 9365 records remained for level one screening. Following screening of titles and abstracts, 144 full-text articles were retained for level two screening, with 100 studies identified as eligible (see online supplemental file 3 for references).

The included studies were published from 1 January 1990 to 13 February 2020, with only 15% published in the past 5 years. Studies were conducted among 17 (47%) high-income OECD countries; the number of studies per country ranged from 1 (six countries) to 23 (one country). The most studied countries included the USA (23%), Australia (12%) and Canada (10%).
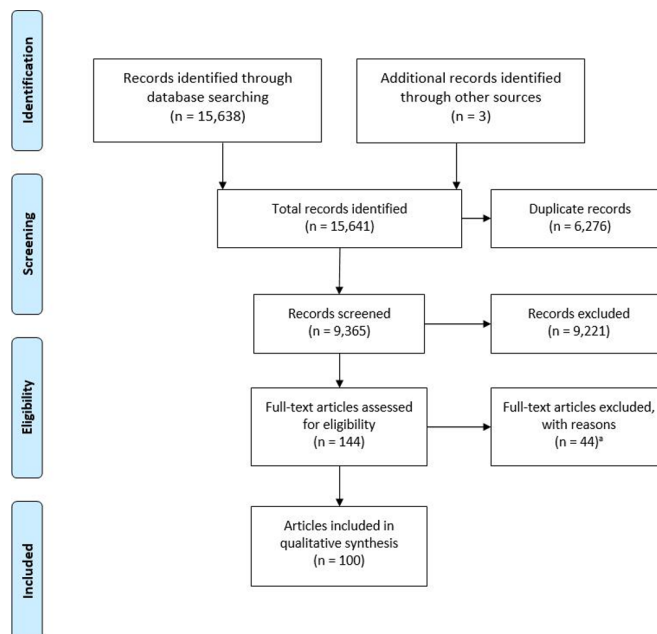
Figure 1 PRISMA flow chart for the identification, screening, eligibility and inclusion of articles. [a]Reasons for exclusion: 18 studies were not peer-reviewed articles; 9 studies did not evaluate a universal suicide prevention intervention; 11 studies did not use suicide mortality as an outcome; 2 studies were not conducted in a high-income OECD country and 4 studies did not have the full-text article available. OECD, Organisation for Economic Co-operation and Development; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

The majority of included studies (n=66) investigated law and legislation reform interventions (eg, alcohol and tobacco taxes, catalytic converter legislation, laws banning the use of pesticides, etc), with 45 out of the 66 studies investigating firearm-related law interventions. For firearm restriction laws, the most common topics of study were the US Brady Handgun Violence Prevention Act, the Australian National Firearms Agreement (NFA) and the Canadian Bills C-51 and C-17. Thirteen studies investigated physical barriers for suicide prevention (eg, installed on bridges or other jumping sites, train stations), nine investigated community-based interventions (eg, one intervention focused on improving the care of patients with depression by training family doctors, conducting media and general public campaigns, using community facilitators and fostering self-help activities), four investigated communication strategies (eg, media reporting and public awareness campaigns), seven reported on mental health policies and strategies (eg, a new suicide prevention policy) and one investigated access to healthcare as a method to prevent suicide. Tables 1–5 and online supplemental files 4–5 display details on all studies included in this review.

The overall summary of the findings is outlined in table 5. Thirteen (100%) physical barrier studies reported favourable results, as did two of four (50%) communication strategy studies, and three of nine (33%) community-based interventions. In total, 46 of 66 (70%) law and regulation reform studies reported favourable results, of which 30 of 45 (67%) firearm-related studies reported favourable results. Several specific interventions were the topic of multiple papers. The proportion of studies reporting a novel intervention was 75% for communication strategies, 78% for community-based interventions, 44% for law and regulation reform, 100% for mental health policies and strategies, and 85% for physical barriers. The study-specific

Table 1 Access to healthcare

Study	Design	Time period	Country (region)	Intervention	Results	Direction of association
Lester *et al*, 1996[51]	Time-Series	1971–1989	Japan	Opened 35 suicide prevention centres during the intervention period.	Suicide prevention centres were associated with reductions in suicide mortality among men (β=−0.52; p<0.05) but not women (β=0.07) only when adjusting for birth rate.	Total: - Male: -- Female: +

--, statistically significant reduction; β, beta coefficient; -, not statistically significant reduction; +, not statistically significant increase.

quality assessment ranged from weak to strong, depending on the intervention category. Details on the study quality assessment scoring can be found in online supplemental file 6.

DISCUSSION

The WHO comprehensive framework launched in 2014 emphasised the importance of using a range of suicide prevention strategies (including universal, selective and indicated interventions),[11] at different levels based on the unique situation and distribution of risk factors in each country. Relatively few studies have examined the effectiveness of universal suicide prevention interventions, with many doing this in combination with selective and indicated interventions. To the best of our knowledge, this is the first systematic review to examine the effectiveness of universal suicide prevention interventions with suicide mortality as the outcome.

Overall suicide mortality

This systematic review examined results from 100 studies conducted in 17 high-income OECD countries that investigated the association between specific universal suicide prevention interventions and changes in suicide mortality. Overall, we found that the relationship between universal suicide prevention interventions and reductions in suicide mortality varied largely depending on the type of intervention. We found that nearly all physical barriers interventions (100%) were effective at reducing suicide mortality at specific sites. The majority of the included studies in our study investigated law and legislation reform interventions, with roughly three-quarters (70%)

of the included studies showing significant reductions in suicide mortality. Due to the reach of these interventions, they should be considered an important component of universal suicide prevention. Previous reviews have reported similar results by demonstrating that the most promising universal interventions were laws and legislative reforms restricting means to suicide (eg, guns, domestic gas, barbiturates, vehicle emissions, analgesics, pesticides, etc) and the control of locations frequently used for suicide by jumping (eg, physical barriers).[20 21] Similar to other reviews, limited evidence demonstrated the effectiveness of communication strategies (eg, general public education and media guidelines) or community-based interventions (multilevel interventions) on suicide mortality. In our review, community-based interventions were often multi-level making it difficult to identify which specific components of the intervention had direct impacts on suicide mortality. Also, the evaluation of some of the community-based interventions combined suicide attempts and suicide deaths, further complicating the comparability of findings. In our review, we also included a broad range of interventions, such as healthcare access interventions and mental health policies (eg, national strategies, plans, health insurance policies). These types of interventions had limited impacts, except for mental health policies, which were significantly effective among specific age categories.

Sex-stratified results

Overall, there was more evidence supporting the effectiveness of universal suicide prevention interventions among males compared with females. Of the 27 studies that reported sex-specific effects,

Table 2 Communication strategies

Study	Design	Time period	Country (region)	Intervention	Results	Direction of association
Etzersdorfer and Sonneck 1998[52]	Prospective Field Experiment	1980–1996	Austria (Vienna)	National media reporting guidelines for suicide were released in mid–1987.	Following the implementation of the media reporting standards the number of people who died by suicide on the Viennese subway system dropped from nine in 1987 to two in 1988.	Total: -
Niederkrotenthaler and Sonneck, 2007[53]	Interrupted time series	1946–2005	Austria	National media reporting guidelines for suicide were released in mid–1987.	The media guidelines were associated with a significant reduction in the number of annual suicide mortalities (β=−80.95; 95% CI −149.11 to −12.78; p=0.024).	Total: --
Till *et al* 2013[54]	Pre–post, with control group	2011	Austria (Styria)	In 2011, the city of Styria launched an awareness campaign through billboards and info screens in public areas aimed at suicide prevention and increasing help seeking behaviours.	There was a small increase in the number of suicide mortalities from 52 during the control period (January–March) to 69 during the intervention period (April–June) in 2011 (χ^2=1.13; p=0.28).	Total: +
Matsubayashi *et al* 2014[55]	Time series	2010–2012	Japan (Nagoya)	In 2009, a city-wide campaign was launched to increase the awareness of depression and heighten help seeking behaviours.	There was a significant decrease in the number of suicides 2 months following the distribution of campaign materials (incidence rate ratio=0.97; 95% CI 0.96 to 97). The impact was greater in men compared with women.	Total: -- Male: -- Female: --

+, not statistically significant increase; -, not statistically significant reduction; β, beta coefficient; --, statistically significant reduction; ++, statistically significant increase.

Table 3 Mental health policies and strategies

Study	Design	Study time period	Country (region)	Intervention	Results	Direction of association
Ohberg et al 1997[S81]	Time series	1980–1995	Finland	In 1990, a national suicide prevention project was implemented.	There was a significant decline in suicide rates among men aged >15 years from 61.7 deaths per 100 000 in 1990 to 54.1 in 1995, with the largest impact occurring in youth aged 15–24 years. The decline in suicide rates among women was not significant.	Male 15–24 years: -- 25–34 years: - 35–64 years: - >65 years: - Female 15–24 years: - 25–34 years: + 35–64 years: - >65 years: -
Bellanger et al 2006[S82]	Quasi-experimental	1988–2001	France	Since 1994, a new suicide prevention policy has been introduced in France.	Following the implementation of the new policy, the decrease in suicide rates was significantly greater in the exposed group (−12.7%) compared with the non-exposed group (−7.6%), after adjusting for sex and initial death rates.	Total: --
Nakanishi et al 2020[S83]	Interrupted Time series	1996–2016	Japan	In 2006, the Basic Act for Suicide Prevention implemented, which included nine initiatives that covered almost all aspects of suicide prevention, with the exception of policies to reduce harmful alcohol use.	After the 2006 implementation of the Act, there was a reduction in suicide mortality across most age and sex groups (April 2006–February 2011), but none of the reductions were considered statistically significant.	Total: - Male: - Female: + ≤19 years: - 20–39 years: - 40–59 years: - >60 years: +
Lee et al 2018[S84]	Time series	1993–2016	South Korea	In the early 2000s (first: year 2004; second: year 2009), South Korea implemented the national suicide prevention programme, which included different suicide prevention policies for both high-risk groups, and the general population.	From 1993 to 2010, the national suicide mortality rate increased by an annual percent change of 5.6% (95% CI 4.4% to 6.9%). After 2010, the suicide mortality rate declined by an annual percent change of 5.5% (95% CI −10.3% to −0.5%) until 2016.	Total: -- Male: - Female: --
Baran et al 2015[S85]	Pre–post with no control group	2002–2014	Sweden	In 2008, the Swedish government approved a national programme for suicide prevention that recommended nine strategies. Specific details on the programme are not provided.	Before the implementation of the national programme, the suicide rate in Sweden was 12.9 per 100 000 (2002–2007), which declined to 12.33 per 100 000 following the implementation (2009–2014). The overall slope of the regression was not significant, suggesting that the programme had a minimal impact on suicide rates. The programme may have only reduced suicide rates in older men age >65 years (2.41 suicide rate reduction, p=0.02).	Male 0–24 years: + 25–44 years: - 45–64 years: - >65 years: -- Female 0–24 years: + 25–44 years: - 45–64 years: - >65 years: -
Lang, 2013[S86]	Pre–post, with control group	1990–2004	USA	States began enacting mental health insurance laws between the mid-1990s and early 2000s. By 2002, 45 states had enacted some type of mental health insurance law.	Following the enactment of mental health insurance laws that were at parity physical health insurance laws in 29 states, the state-level suicide rate was 10.24 per 100 000. If these laws were not enacted the suicide rate would have been 10.61 per 100,000, which equates to approximately 592 suicide deaths prevented per year.	Total: --
Matsubayashi et al 2011[S87]	Pre–post, with no control group	1980–2004	11 high-income OECD countries	Between 1995 and 2003, 11 high-income OECD countries had implemented a nationwide suicide prevention programme. These programmes varied by country, were multifaceted and include a variety of activities, some of which constituted universal interventions.	Following the implementation of a national suicide prevention programme, the national suicide rate per 100 000 declined by 1.38 (SE=0.5, p<0.05). The effect was larger in men (suicide rate=−1.43, SE=0.513, p<0.05) than women (suicide rate=−0.37, SE=0.51, not significant).	Male 0–24 years: -- 25–64 years: - >65 years: -- Female 0–24 years: -- 25–64 years: + >65 years: --

+, not statistically significant increase; -, not statistically significant reduction; --, statistically significant reduction; ++, statistically significant increase; OECD, Organisation for Economic Co-operation and Development; SE, SE error.

eleven (41%) found strong evidence of reductions in suicide mortality for males, but not for females (S1, S18, S29, S32, S33, S44, S79, S81, S83, S87, S100). While 12 (44%) reported equal effectiveness between males and females (S5, S11, S16, S17, S20, S23, S30, S43, S54, S55, S60, S85) and 4 (15%) reported effective results for females only (S7, S22, S42, S84). In Western contexts, more females attempt suicide, while more males die by suicide. This is known as the 'gender paradox' of suicide.[27] The greater number of studies with positive results for males may be due, in part, to the significantly higher levels of suicide death among males and the greater power to detect significant effects.

It is also possible that different types of interventions may be effective for females as compared with males, particularly as they relate to means restrictions. For example, while means restrictions interventions have been widely applied to more violent forms of suicide which are more common among men, including firearm suicide and jumping from heights, means restriction for some methods more common among women, such as poisoning by drugs,[28 29] may be somewhat more challenging to implement. Finally, it is possible that the use of coroner or medical examiner data, which have been shown to have a lot of missing data, particularly for antecedents of suicide attempts and recent

Table 4 Physical barriers

Study	Design	Study time period	Country (region)	Intervention	Results	Direction of association
Law et al 2014[S88]	Pre–post, with no control group	1990–2012	Australia (Brisbane)	In 1993, a fence barrier on the Gate Bridge in Brisbane was first installed, and later replaced in 2010 to deter individuals from dying by suicide while jumping off the bridge.	Following the installation of the barrier the suicide rate per 100 000 declined from 0.67 in 1990–1993 to 0.32 in 1994–1997, representing a 53% rate reduction. The suicide rate from the Gate Bridge continued to fall with each subsequent year. Following the installation of the new barrier in 2010 there were no suicide mortalities recorded from the bridge (2010–2012).	Total: --
Perron et al 2013[S89]	Time series	1990–2009	Canada (Montreal)	In 2004, the construction of a barrier on the Jacques-Cartier Bridge was completed to help deter suicide by jumping.	The suicide rate following the completion of the bridge barrier showed a steep decline in suicide by jumping (incidence rate ratio=0.24; 95% CI 0.13 to 0.43).	Total: --
Sinyor et al 2010[S90]	Time series	1993–2007	Canada (Toronto)	Between 2002 and 2003 a barrier was built on the Bloor Street Viaduct called the 'luminous vail'.	Following the installation of a bridge barrier on the Bloor Street Viaduct the mean number of suicide mortalities declined from 9.3 (1993–2002) to 0 (2004–07) (incidence rate ratio=0.05; 95% CI 0.01 to 0.31).	Total: --
Sinyor et al 2017[S91]	Pre–post, with no control group	1993–2014	Canada (Toronto)	Between 2002 and 2003 a barrier was built on the Bloor Street Viaduct called the 'luminous vail'.	A per-capita rate of 9.0 suicide deaths per year took place prior to the barrier construction, which declined to 0.1 suicide deaths per year after the construction of the barrier (IRR=0.009, 95% CI 0.0005 to 0.19).	Total: --
Matsubayashi et al 2013[S92]	Quasi-experimental	2000–2010	Japan (Tokyo)	Between 2008 and 2010, blue lights-emitting diod (LED) lamps were installed on train platforms at 11 Tokyo railway stations.	Following the installation of blue LED lamps, the number of suicides per year declined by 84% (95% CI 14% to 97%; incidence rate ratio=0.17; 95% CI 0.03 to 0.87).	Total: --
Matsubayashi et al 2014[S93]	Quasi-experimental	2000–2013	Japan	Between 2008 and 2013, 14 railway or metro stations in Japan installed blue light-emitting-diode (LED) lamps to help prevent suicide by jumping onto the rail.	The annual mean no of suicides mortalities at the 14 intervention stations declined from 0.44 to 0.19 following the installation of the blue LED lamps (incidence rate ratio=0.026; 95% CI 0.13 to 0.52), equivalent to a 74% reduction in the number of deaths by suicide.	Total: --
Ueda et al 2015[S94]	Time series	2004–2014	Japan (Tokyo)	On April 2004, 19 of 168 railway stations had half-height platform screen doors installed to prevent access to the rail tracks. Between 2004 and 2014, a total of 52 additional stations were retrofitted with half-height platform screen doors, for a total of 71 stations.	Following the installation of half-height platform screen doors there was a total of 7 deaths by suicide (2004–2014). The incidence rate ratio associated with the installation of the doors was 0.24 (95% CI 0.09 to 0.67), equivalent to a 76% reduction in suicide deaths.	Total: --
Beautrais et al 2009[S95]	Pre–post, with no control group	1991–2006	New Zealand (Auckland)	In 1937, barriers were installed on Grafton Bridge in Auckland, New Zealand. After public complaint about the unsightly barriers, they were removed from the bridge in 1996. In 2003, new barriers were erected on the bridge.	From 1991 to 1995, while the old barriers were erected, there was a mean of 1 suicide by jumping per year. This increased to 3.17 per year from 1997 to 2002 during the period where no barriers were installed. The per year mean number of suicide mortalities by jumping dropped to 0 once the new barriers were constructed on the Grafton Bridge.	Total: --
Skegg et al 2009[S96]	Time series	1996–2008	New Zealand (Dunedin)	Lawyer's Head cliff is a scenic outlook in the city of Dunedin that overlooks the Pacific Ocean. In 2006, vehicle access to the Lawyer's Head cliff was closed for construction.	In the 10-year period prior to the road closure there were 13 suicide mortalities at Lawyer's Head cliff, which was reduced to 0 following the intervention (incidence rate difference=1.3 per year; 95% CI 0.6 to 2.0).	Total: --

Table 4 Continued

Study	Design	Study time period	Country (region)	Intervention	Results	Direction of association
Chung et al 2016[S97]	Time series	2003–2012	South Korea (Seoul)	Between 2005 and 2009, the Seoul Metro installed platform screen doors at 121 subway stations (119 full-height, and two half-height).	There was a total of 3 deaths by suicide following the installation of platform screen doors, compared with 132 deaths by suicide in stations without platform screen doors (incidence relative ratio=0.11; 95% CI 0.03 to 0.43). This was equivalent to an 89% (95% CI 57% to 97%) reduction in suicide deaths following the installation of a platform screen door.	Full-height doors Total: -- Half-height doors Total: +
Reisch et al 2005[S98]	Pre–post, with no control group	1988–2002	Switzerland (Bern)	In 1998, a safety net was installed under the Muenster Terrace to save those who attempt suicide by jumping.	In the 4 years prior to the installation of the safety net six people died by suicide by jumping from the Muenster Terrace. Following the installation, three people jumped from the Terrace, but nobody died at the site.	Total: --
Hemmer et al 2017[S99]	Time series	1990–2013	Switzerland	This study investigated the impact of 15 jump sites in Switzerland with installed suicide-prevention measures (13 bridges, 1 terrace, 1 multistory car park).	The installation of barriers resulted in a prevention rate of 68.7% (rate ratio=0.34; 95% CI 0.18 to 0.64), whereas the installation of safety nets resulted in a prevention rate of 77.1% (rate ratio=0.21; 95% CI 0.07 to 0.62).	All barriers Total: -- Partial barriers Total: -- Full barriers Total: -- Safety nets Total: --
Bennewith et al 2007[S100]	Time series	1994–2003	UK (Bristol)	In December 1998, a barrier was installed on the Clifton suspension bridge in Bristol.	Prior to the installation of the bridge barrier there was a mean of 8.2 suicides by jumping per year (1994–1998), which declined to 4.0 suicides by jumping per year (difference in mean=−4.2; 95% CI −5.9 to −1.4).	Total: -- Male: -- Female: +

++, statistically significant increase; --, statistically significant reduction; -, not statistically significant reduction; +, not statistically significant increase.

events that could have precipitated the suicide,[30 31] explain at least in part the presence or absence of sex differences across studies. Future research using additional information, such as those collected from the psychology of death, is necessary to disentangle sex and gender differences in the universal suicide prevention interventions' effectiveness. Regardless, research on universal suicide prevention interventions' effectiveness should continue to apply a sex and gender lens.

Substitution hypothesis

In this review, 17 studies examined whether restricting suicide means from one method would result in an increase in suicide from other methods, described as the 'substitution hypothesis'.[32] However, findings from those studies are mixed, with eight studies providing evidence to supporting a substitution hypothesis (S19, S25, S26, S38, S54, S55, S90, S93), and nine studies not yielding such evidence (S36, S44, S48, S88, S89, S91, S96, S98, S100). For example, Klieve et al found that when the firearm suicide rate for Australian males declined following the introduction of restrictions on weapon purchases, the rate of suicide death by hanging increased simultaneously (S38). Similarly, Caron et al found that the firearm suicide rate decreased among males in Quebec (Canada) following the implementation of Bill C-17, while the rate of suicide death by hanging increased simultaneously (S55). Conversely, Lester and Leenaars (S50), Carrington et al (S51) and Leenaars and Lester rejected the substitution hypothesis (S52). They found that firearms were not replaced by other methods for suicide following passage and enforcement of Canadian Bill C-51. Several factors could explain these discrepancies, such as the availability of

the method of suicide and study methodology. Duration of the follow-up may also explain these mixed findings across studies. For example, Sinyor et al demonstrated that by extending the follow-up period by seven additional years from a previous study (S90), the substitution hypothesis was no longer supported for suicide mortality by other means (S91). There is also the potential for individuals to switch from one method to another based on availability of means, and based on acceptability and country-specific sociocultural norms that may influence the use of other suicide methods.[33 34]

Years of follow-up

The historical period of our included studies ranges from 1907 to 2020, and consequentially, the length of follow-up across the studies, from less than 5 years (short term), to 20 years and longer (long term). In our review, six studies examined both the short-term and long-term association of the intervention and suicide mortality (S7, S14, S47, S56, S57, S91). Stack et al (S14), examined the short-term and long-term trends in suicide following a crisis phone line intervention to reduce suicide by jumping at the St.Petersburg (Florida) Skyway bridge. They found that over the short term (2 years), there was no impact of the intervention, while 13 years after the intervention, suicide mortality increased, suggesting the need for a more substantial intervention. Sinyor et al (S90), investigated the effectiveness of an intervention to reduce access to a jumping point in Toronto (Canada) with 3 years of follow-up, and found that the intervention, although effective, led to an increase in suicide mortality by other means in Toronto. However, in a 7-year follow-up, the authors found that the intervention was, in fact, more effective

Table 5 Overall summary of findings

Intervention category	# of unique interventions (# of papers)	Pooled time period	High-level findings	Study quality assessment
Access to healthcare	1 (1)	1971–1989	One study reported both null and statistically significant effects for suicide prevention centres on reducing suicide rates among both men and women.	Weak[S1]
Communication strategies	3 (4)	1946–2012	Two studies reported a statistically significant effect for communication strategies on reducing suicide mortality. Two studies reported null findings for the effect of communication strategies on reducing suicide mortality.	Weak to moderate ► 1 weak[S2] ► 3 moderate[S3–S5]
Community-based interventions	7 (9)	1986–2016	Two studies reported a statistically significant effect for community-based intervention on reducing suicide mortality, one study reported both null and statistically significant effects on reducing suicide mortality, one study reported both null and statistically significant effects on increasing suicide mortality and five studies reported null findings.	Weak to strong (largely moderate) ► 1 weak[S7] ► 7 moderate[S8–S14] ► 1 strong[S6]
Law and regulation reform	29 (66)	1907–2017	Of the 21 law and regulation reforms, nine studies reported a statistically significant effect for reforms on reducing suicide mortality, seven showed mixed null and statistically significant effects on reducing suicide mortality, two showed mixed null and statistically significant effects on both increasing and decreasing suicide mortality, and three studies reported null findings. Of the 45 firearm law and regulation reform studies, 19 reported a statistically significant effect for reforms on reducing suicide mortality, eleven studies reported mixed null and statistically significant effects on reducing suicide mortality, five studies reported null and statistically significant effects on both reducing and increasing suicide mortality, and ten studies reported null findings.	Weak to strong (largely moderate to strong) ► 5 weak[S56, S57, S60, S73, S74] ► 32 moderate[S28–S31, S34, S36–S46, S49–S53, S58, S61, S64, S65, S67, S71, S75–S77, S79, S80] ► 29 strong[S15–S27, S32, S33, S35, S47. S48, S54, S55, S59, S62, S63, S66, S68–S70, S72, S78]
Mental health policies and strategies	7 (7)	1980–2016	Two studies reported a statistically significant effect for mental health policies on reducing suicide mortality, four studies reported both null and significant effects on reducing suicide mortality and one study reported null findings.	Moderate to strong ► 3 moderate[S82, S84, S85] ► 4 strong[S81, S83, S86, S87]
Physical barriers	11 (13)	1988–2014	Eleven studies reported statistically significant effects for physical barriers on reducing suicide mortality, and two studies reported both null and statistically significant effects on reducing suicide mortality.	Moderate to strong (largely strong) ► 3 moderate[S92, S94, S100] ► 10 strong[S88–S91, S93, S95–S99]

in the long term (S91). This suggests that some universal interventions might not be short-term solutions, as they may be more likely to be effective in the long-term period. The lower base rate of suicide mortality may also result in few events over short-term periods, with longer follow-up being needed to have adequate power to detect significant effects. Many of the studies that have used short-term follow-up period (eg, (S56) and (S57)) found no statistically significant changes in suicide mortality. In contrast, many studies with longer-term follow-up periods (eg, (S47)) showed that suicide mortality was significantly lower after the intervention and over time (~10 years after implementation).

Sustainable Development Goals
Our systematic review highlights a number of universal interventions that hold promise for reducing suicide mortality, such as law and legislation reforms and physical barriers. It is likely that to meet the SDGs to reduce suicide mortality rates, countries will need to take a multilevel approach that incorporates a variety of universal, selective and indicated interventions. Future research should focus on how universal interventions act in synergy with targeted and indicated approaches to reduce suicide mortality, identifying well-designed and transferrable interventions that

can strengthen suicide prevention efforts within countries to meet the SDG target.

Strengths and limitations
The current systematic review has several strengths. First, we followed PRISMA guidelines to identify relevant studies, appraised the study-specific risk of bias (study quality assessment), and synthesised the results in a transparent, unbiased and reproducible manner. Second, the review captured a large number of studies on universal suicide prevention intervention published in English or French across 17 high-income OECD countries. Third, studies used a wide range of study designs with most of the primary data used in these studies being obtained from reliable sources (eg, vital statistics, coroners and medical examiners data). Fourth, we used the EPHPP Quality Assessment Tool to assess the quality of all included studies, this tool is widely used and designed to assess the quality of the evidence to support public health interventions and related research.[26] Fifth, we ensured that studies evaluated the same interventions were identified to avoid 'double-counting' interventions. Sixth, while randomised controlled trials are considered the gold standard in intervention evaluation, this design would be regarded

as unethical, not feasible politically, nor appropriate in the case of universal suicide prevention interventions.[35] The natural experiments summarised in our study provide an excellent way to overcome the drawbacks of randomised controlled trials while still providing a way to study the impact of real-world interventions. Unfortunately, few studies evaluated concurrent universal interventions or interventions across multiple jurisdictions. Not all used a comparison group, but having a 'control' group without randomisation strengthened the study design in a number of cases. Finally, some studies used a repeated cross-sectional design, which is not as strong as longitudinal designs. There may be issues with internal validity because of unmeasured changes in the samples' composition over time.

The quality of studies included impacts the confidence of the conclusions derived by a systematic review. The current systematic review included a large and diverse number of studies from around the world, providing more confidence to our findings. Second, due to heterogeneous data, we were unable to perform a meta-analysis to identify the pooled effects for each category of universal suicide prevention interventions. Third, the present systematic review did not identify any significant differences in intervention effectiveness by race, ethnicity, or immigration status, which represent important areas of future research. Fourth, we did not include studies published before 1 January 1990, and as a result, we may have missed some important studies published before this date. However, it is important to note that this study included many interventions implemented prior to 1990, but evaluated and published after 1990. Additionally, the policies enacted during these times may have less relevance in more recent contexts. We also may have missed important studies conducted in countries outside of the high-income OECD context. Finally, it is important to recognise the variability and incomplete nature of the information collected by coroners and medical examiners within and between countries,[30 31] particularly on antecedents of suicide attempts and recent events, that could have precipitated the death by suicide.

CONCLUSIONS

This systematic review among high-income OECD countries found that universal suicide prevention interventions, especially those that include physical barriers and law and regulation reforms, were largely effective in reducing suicide mortality among the countries included in this study. While they are generally effective, their success widely varied by intervention type, follow-up period and sex. When investigating universal suicide prevention interventions, researchers should make an effort to stratify results by sex and to investigate the short-term and long-term impact of the interventions.

What is already known on the subject

► Suicide continues to be a leading cause of death worldwide, and a significant public health concern.

What this study adds

► Universal suicide prevention interventions provide an effective means to reduce suicide mortality in high-income OECD countries.
► Physical barriers and law and regulation reform interventions seem to hold the most promise in preventing suicide.

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