Original Article

DOI: 10.7860/JCDR/2023/61802.18520

Potential Determinants of Mass Shooting Perpetration and Casualties: A Systematic Review

Epidemiology Section

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ABSTRACT

Introduction: In the United States (US), mass shootings could be regarded as a public health issue due to their ubiquitous and public nature. Social-ecological models, commonly used to explain health behaviours, can contribute to the understanding of potential determinants of mass shootings based on current evidence.

Aim: To conduct a systematic review on factors associated with the perpetration of mass shooting events and casualties (injuries or fatalities) at mass shooting events.

Materials and Methods: The author searched the literature on PubMed using the term "mass shooting". Inclusion criteria included titles containing the words "shoot*," "firearm*," or "gun*," having an abstract or full text, and the study being either primary research or secondary data analysis on the perpetration or casualties of mass shootings.

Results: The author reviewed 36 articles, nearly all of which focused on mass shootings in US. For the perpetration of mass shootings, gun ownership and access were present at all levels of the social-ecological model. Other factors for perpetration included mental illness, relationship issues, and permissive firearm laws. Mass shooting casualties were associated with the use of high-powered firearms at the intrapersonal level and permissive firearm laws at the policy level.

Conclusion: Firearms-related factors were associated with both the perpetration and casualties of mass shootings at various levels of the social-ecological model. However, caveats, including a limited time frame of the review, limited sources of publications, and subjectivity in building the social-ecological model, should be considered in the interpretation of the study findings.

Keywords: Aggression, Criminal behaviour, Firearms, Social-ecological model

INTRODUCTION

On May 14, 2022, an 18-year-old male entered Tops Friendly Markets supermarket in the city of Buffalo, New York, USA, and opened fire with a Bushmaster AR-15 style semi-automatic rifle, killing 10 people. His apparent motivation was linked to white supremacy [1]. Ten days later, another 18-year-old male entered Robb Elementary School in the city of Uvalde, Texas, USA, and opened fire with a Daniel Defense AR-15 style semi-automatic rifle, resulting in the deaths of 19 school children and two teachers [2]. These incidents are categorised as mass shootings, which are typically defined as instances of gun violence unrelated to armed conflicts or domestic violence, resulting in three or more casualties (injuries or deaths), excluding the perpetrator(s) [2].

While mass shootings can occur in various countries, the US stands out as the only country in the Organisation for Economic Cooperation and Development (OECD) where public mass shootings occur every year, accounting for over 70% of such incidents in high-income countries [3]. Additionally, mass shootings in the US often take place in public spaces. For instance, the deadliest mass shooting incident occurred in 2017 in Las Vegas, when a 64-year-old male, armed with 24 rifles, opened fire on attendees of the Route 91 Harvest Country music festival from his hotel room window. This incident resulted in the deaths of 58 people and injuries to more than 500 individuals [4].

Considering the significant increase in gun manufacturing and import in the US over the past decade [5], as well as the country's highest civilian firearm ownership rate in the world at 120 firearms per 100 residents [6], it can be argued that no population subgroup is immune to gun violence and mass shootings. Thus, mass shootings (and by extension, gun violence) can be viewed as public health issues in the US. As public health issues, efforts to prevent mass shootings should entail both primary prevention (preventing the perpetration of mass shootings) and secondary prevention (minimising casualties during such events). Taking a public health perspective, the perpetration and casualties of mass shootings should not only be attributed to the characteristics of the perpetrators themselves, as portrayed in the media and certain literature, but also to social and environmental factors. Thus, the social-ecological model for health behaviours can be a valuable framework for examining the determinants of mass shootings, enabling relevant stakeholders to consider this phenomenon in a more comprehensive manner [7].

In response to the incidents in Uvalde and the increasing frequency of mass shootings, bipartisan agreement has been reached among US legislators regarding federal-level firearm safety laws [8]. Conducting a systematic review on the determinants and casualties of mass shootings, along with interpretation using the social-ecological model, has the potential to inform relevant stakeholders and the public about the alignment between proposed firearm safety policy legislation and the body of empirical evidence. It can also shed light on whether there are additional determinants of mass shootings that should be considered in future agendas. The objective of the present review was to assess the factors associated with the perpetration of mass shooting events and the number of casualties (injuries or fatalities) at such events.

MATERIALS AND METHODS

Population, Intervention, Control, Outcomes (PICOs): Population= Mass shooting events;

Intervention=Characteristics at various levels of the social-ecological model;

Control=Not applicable;

Outcomes=1) perpetration of mass shootings; 2) number of casualties.

Inclusion criteria: Studies with the titles containing the words "shoot*," "firearm*," or "gun", articles with abstracts or full text and primary research or secondary data analysis on the perpetration or casualties of mass shootings were included in the present review.

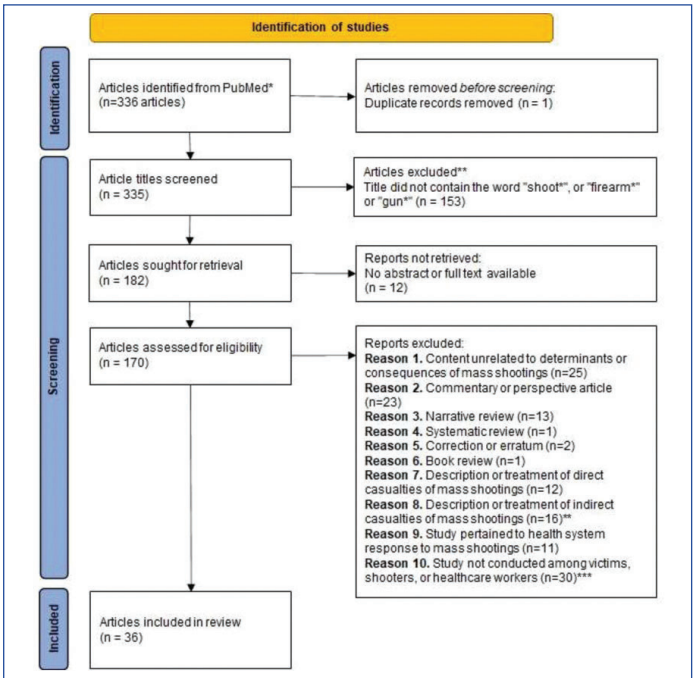
Exclusion criteria: Content unrelated to determinants or consequences of mass shootings, commentary or perspective articles, narrative reviews, systematic reviews, corrections or errata, book reviews, descriptions or treatments of direct casualties of mass shootings, descriptions or treatments of indirect casualties of mass shootings, studies pertaining to health system responses to mass shootings and those not conducted among victims, shooters, or healthcare workers were excluded from the present review.

Study Procedure

The present review sourced its information from PubMed Central (PMC).

Search strategy: On June 2, 2022, the author conducted a literature search on PubMed Central (PMC). The search was limited to articles published in English from January 1, 2017, to the date of the search. The search term used was "mass shooting." The author chose 2017 as the starting year due to the deadliest mass shooting in US history occurring that year.

Selection process: The author excluded duplicate articles, screened the titles of the searched articles, excluded articles without abstracts or full text available, and then individually assessed each article for eligibility to be reviewed in full based on the eligibility criteria. The process and the number of publications excluded at each step can be found in [Table/Fig-1].



[Table/Fig-1]: PRISMA 2020 flow diagram for inclusion of articles indexed in PubMed for the review.
*Search term "mass shooting", filter applied to within the last five years (2017-2022)
**Including family or classmates of direct casualties and individuals affected by vicarious trauma
***Including but not limited to media studies, changes in public opinion, changes in gun ownership

Data collection process: The author read the content of the eligible articles, summarised the findings, and assigned a unique ID to each article for ease of reference during interpretation and summary.

Synthesis methods: The author applied the social-ecological model [7] to identify factors associated with the perpetration and casualties of mass shooting events. Separate analyses were conducted for factors associated with the perpetration of mass shooting events and factors associated with the casualties of mass shooting events. The present systematic review did not involve the use of human subjects.

RESULTS

Study flow and characteristics of included studies: Initially, the author found 336 articles through a search on PubMed, of which one was a duplicate and subsequently removed [Table/Fig-1]. The author screened the titles of the remaining 335 articles and excluded 153 articles that did not contain the words "shoot*," "firearm*," or "gun*" in the title. The author then attempted to retrieve the remaining 182 articles, but 12 of them did not have an abstract or full text available. The author assessed the remaining 170 articles for eligibility and excluded 134 articles for various reasons, ultimately including 36 research articles in the review and assessment using the social-ecological model.

All but two of the reviewed articles focused on mass shootings in the US. One article analysed non war mass murders worldwide, including those not involving firearms, while another article examined Australian mass shooting incidents and offenders from 1964 to 2014 [Table/Fig-2] [9-44]. All articles were ecological, cross-sectional, or panel studies. One study, which described itself as a "cohort study," did not follow a defined cohort but instead examined the location of mass shootings relative to schools and places frequented by children.

Factors associated with the perpetration of mass shootings: Intrapersonal factors associated with mass shootings included mental illness and experiences of acute life stressors [Table/Fig-3]. Intrapersonal issues included mental illness, behavioural problems, and gun ownership were identified. Interpersonal issues related to behavioural problems, such as family dysfunction and estrangement, were also positively associated with the perpetration of mass shootings. Gun ownership and access to firearms were present at the community level. At the policy level, firearm safety measures had a negative (preventive) association with mass shooting perpetration.

The term "positive" refers to a factor being positively associated with the outcome (i.e., the higher the level of the factor, the higher the likelihood of mass shooting perpetration). The term "negative" refers to a factor being negatively associated with the outcome (i.e., the higher the level of the factor, the lower the likelihood of mass shooting perpetration). The term "neutral" indicates that a factor did not have any statistically significant association with the outcome (i.e., no association).

ID	Author and year; study design, population, and setting	Objective(s)	Results
1	(Reeping PM et al., 2022) [9] Secondary data analysis (n=unknown; US states)	• To identify factors associated with intentional school shootings.	• State-level firearm laws permissiveness and rate of gun ownership were associated with higher rates of school shootings and active school shootings.
2	(Silver J and Silva JR, 2022) [10] Secondary data analysis (n=unknown; mass shooters)	• To assess the order in which public mass shooters encountered behavioural and experiential factors.	• Shooters lived in coherent phases. • There was centrality of family problems and interest in pass mass killings in the overall sequence.
3	(Duchesne J et al., 2022) [11] Secondary data analysis (n=2736 mass shooting events; US)	• To assess the association between strength of state gun laws and incidence of mass shooting event.	• The mean mass shooting incidence in states with weakest gun laws increased from 4.0 per million in 2014 to 9.7 per million at time of study. • There were no significant differences in number of mass shooting events per year by gun law grade, before and after adjusting for population.
4	(Cerfolio NE et al., 2022, p. 20) [12] Secondary data analysis (n=55 mass shooters, US)	• To understand the underlying psychiatric, psychosocial, and psychodynamic of mass shootings in the US.	• The majority of shooters (87.5%) were not diagnosed or received a misdiagnosis or incorrect treatment for mental illness. • Most assailants experienced severe estrangement from families, friends, classmates, and themselves. • Marginalisation and estrangement rendered the shooters more vulnerable to the psychiatric illness and led to online radicalisation, which fostered violence.

5	(Freitas C and Annas GD, 2022) [13] Cross-sectional study (n=9 gun sellers, Onondaga County, New York state, US)	• To describe the opinions, beliefs, attitudes, and current practices of gun sellers in Onondaga county, NY, in regard to safe gun sales.	• Investigators sent 72 surveys to gun sellers, two were undeliverable, and nine sellers returned questionnaires (response rate=9/70=12.9%). • Sixty-two percent (62.5%) of respondents had prior experience in uniform services, including specialised training in mental or emotional crises and deception detection. • Sales denial occurred in 25 of 1471 weapons and ammunition sale made by all qualifying respondents (1.7%). • Of the 25 details, 15 were National Instant Criminal Background Check System (NICS) denials, and 10 were personal denials. • Reasons for personal denials included "interest in illegal fittings", "information revealed during conversations", and "lack of basic knowledge of using the firearm looking to purchase". • None of the respondents reported any buyer to law enforcement. • Barriers to reporting to law enforcement included lack of reporting protocol.
6	(Peterson J et al., 2021) [14] Cross-sectional study (n=150 mass public shooters from 1966-2019, USA)	• To examine prevalence of communication of intent to do harm preceding the shooting.	• Overall, 70 mass shooters (46.5%) leaked their plans. • Leakage was significantly associated with receiving counseling and suicidality.
7	(Peña PA and Jena A, 2021) [15] Secondary data analysis (n=7500 sources, USA)	• To analyse changes in mass shootings in the US during the Coronavirus Disease-2019 (COVID-19) pandemic.	• An increase in mass shootings was observed from May 2020 onward compared with the trends in the years prior. • Following April 16, 2020, there were 0.78 additional daily mass shootings, 0.49 additional people killed daily, and 3.40 additional people injured daily in mass shootings. • Increase in number of fatalities occurred mostly in cities with low and high frequency of pre-pandemic mass shootings. • Findings were robust to alternative start dates for the pandemic, alternative time trends, and varying definitions of mass shootings.
8	(Kowalski RM et al., 2021) [16] Secondary data analysis (n=57 school shootings+24 university shootings+77 mass shootings, USA, since 2003)	• To examine the extent that each type of mass shooting differed with regard to antecedent factors.	• School (k-12) shooters were more likely than other types to have a history of rejection. • Mass shooters were more likely than other types to have experienced acute rejection (e.g., workplace firing). • Other characteristics of K-12 shooters were also common in university and mass shooters.
9	(Lankford A and Silva JR, 2021) [17] Cross-sectional study/Case-series (n=14 deadliest public mass shooters since Columbine Massacre, USA)	• To describe the timing of the presentation of variables for public mass shootings occurrence.	• Mental health contacts often began more than a decade before the attacks and ended more than a year before the attacks. • Work and school problems also typically began long before mass shootings and continued closer to the attacks. • Nearly all shooters (93%) had atleast one work or school problems before acquiring any firearms, and 79% had atleast one mental health contact before acquiring any firearms. • Nearly all shooters (92%) acquired atleast one firearm after last mental health contact. • Firearm acquisition often occurred in the final stages. • Median time from first firearm acquisition to attack was seven months, and median time from last firearm acquisition to attack was one month.
10	(Glick ID et al., 2021) [18] Retrospective observational study (n=35 persons who committed mass shootings between January 1982 to September 2019 and survived, USA)	• To describe the "mass shooters" and history of psychiatric illness, diagnosis, and treatment.	• Among the 35 persons analysed, 28 persons (80%) had a psychiatric diagnosis. • Diagnoses included schizophrenia (18 persons), bipolar disorder (three persons), persecutory delusional disorder (two persons), personality disorder (two persons), substance-related disorders without other diagnoses (two persons), and post-traumatic stress disorder (one person). • None of those diagnosed with psychiatric illnesses were treated with medication.
11	(Geller LB et al., 2021) [19] Retrospective observational study (n=110 mass shootings in 2014-2019, USA)	• To explore the role of domestic violence in mass shootings in the US.	• Most mass shootings (75 of 110) were either related to domestic violence or the shooter had a history of domestic violence. • Domestic violence-related shootings had higher case fatality (83.7%) than shootings not related to domestic violence (63.1%).
12	(Boyd P and Molyneux J, 2021) [20] Secondary data analysis (n=4 datasets on mass shootings, USA)	• To examine the evidence of the existence of contagiousness of mass shootings.	• Number of offspring events per one shooting event in the study databases ranged from 0.46 to 0.90. • In general, the value of temporal triggering function decreases over time.
13	(Post L et al., 2021) [21] Secondary data analysis (n=170 mass shooting events, years 1966-2019, US)	• To determine if the Federal Assault Weapons Ban (FAWB) (1994-2004) reduced the number of public mass shootings while it was in place.	• The FAWB resulted in a significant decrease in public mass shootings. • Authors estimated that the ban prevented 11 public mass shootings. • Continuation of the ban would have prevented 30 public mass shootings that killed 339 people and injured an additional 1139 people.
14	(Brucato G et al., 2021) [22] Cross-sectional study (n=1723 murder incidents; 1315 mass and 408 spree murders, year 1900-2019, worldwide)	• To describe the prevalence of psychosis and mental illness in mass shooting incidents.	• Of the 1315 mass murders, 65% involved firearms. • Lifetime psychotic symptoms were noted among 11% of mass murder perpetrators (18% of those who used firearms, 8% of those who did not use firearms) (p-value <0.01). • Number of mass shootings in the USA between 1900 to 2019 was 3 times higher than the rest of the world during the same period combined. • Compared to the rest of the world, mass shootings in the USA had lower mean fatalities, but shooters in the USA had higher prevalence of non psychotic psychiatric/neurologic symptoms, history of recreational drug use or alcohol misuse, and legal history. • Within the USA, fatality in mass shootings post-1970 was higher in cases involving semi-automatic or automatic firearms than cases with non automatic firearms. • Within the USA, mass shooters post-1970 who used semi-automatic or automatic firearms were more likely to have history of psychiatric or neurologic symptoms than shooters who used non automatic firearms.
15	(Peterson J et al., 2021) [23] Cross-sectional study (n=133 cases of school shooting, year 1980 to 2019, USA)	• To examine the association between presence of an armed officer on scene and the severity of shootings in K-12 schools.	• Armed officer was present in 29 of the 133 cases (23.6%). • After controlling for location and school characteristics, presence of armed officer was associated with higher rate of fatality (IRR=2.96; 95% CI=1.43-6.13), but not higher rate of injury (IRR=1.21; 95% CI=0.69-2.11).

16	(Silva JR et al., 2021) [24] Cross-sectional study (n=unknown, mass shooters, year 1966 to 2018, USA)	• To examine the incidence rate, motivations, and characteristics of gender-based mass shootings in the US from 1966-2018.	• During the study period, there were 106 gender-based mass shooters (34% of all mass shooters). • Compared to other mass shooters, gender-based mass shooters were significantly more likely to be separated/divorced, to have children, to have a history of domestic violence, to have a substance abuse history, but less likely to be single. • The majority of gender-based mass shootings were specific woman-targeted (47%) and specific woman-not targeted (33%). • Motivations for gender-based mass shootings were associated with race, relationship status, and domestic violence history. • General women-not targeted shooters had higher average fatalities (10 deaths) than other types (3-5 deaths).
17	(Siegel M et al., 2020) [25] Ecological study (n=155 mass shooting events, period 1976-2018, USA)	• To analyse the relationship between state firearm laws and the incidence and severity (i.e., number of victims) of mass public shootings.	• State laws requiring a permit to purchase a firearm were associated with lower odds of mass public shooting (-60%; 95% CI=-32%, -76%). • Large-capacity magazine bans were associated with lower fatalities (-38%; 95% CI=-12%, -57%) and lower nonfatal injuries (-77%; 95% CI=-43%, -91%) when a mass shooting occurred.
18	(Nance ML et al., 2020) [26] "Cohort" study (n=418 mass shootings, USA, year 2019)	• To examine the location of mass shootings relative to schools and Places Of Interest (POI) frequented by children.	• The 418 mass shooting events occurred in 40 states, with 2178 people shot (case fatality=21.2%). • A total of 224 children (<18 years) were shot in 121 events (28.9%), with 182 injured and 42 killed (case fatality=42/224=18.8%). • One in 5 mass shootings occurred within <=0.1 miles of a school or place of interest. • More than 90% of mass shootings occurred within 1 mile of a school or POI. • Median distance from event to a school was 0.4 miles, and median distance to a POI was 0.7 miles. • Overall, 9.6% of mass shootings occurred at a school or POI.
19	(Ruderman D and Cohn EG, 2021) [27] Cross-sectional study (n=2081 multiple victims shooting events, January 2014 to December 2019, USA)	• To examine exogenous factors related to the incidence of multiple-victim shootings (specifically, temporal patterns and temperature variation).	• Multiple-victims shooting events were significantly more frequent on weekends, some major holidays (New Year's day, Independence day, Christmas day), hotter seasons (weekday rate in June=0.9; 95% CI=0.80, 1.06; weekday rate in December=0.4; 95% CI=0.35, 0.52), and when temperature was higher than usual.
20	(Kim D, 2019) [28] Cross-sectional study (n=11,385 firearm homicide incidents, January 2015-December 2015, USA)	• To conduct a comprehensive and comparative lagged, multilevel investigation of major social determinants of health in relation to firearm homicides and mass shootings.	• Of the 11,385 firearm-related homicides in 2019, there were 141 mass shootings (1.2% of all incidents). • Institutional social capital at the county level was the only factor marginally associated with mass shootings after adjusting for social mobility and all other social determinants (IRR=0.74; 95% CI=0.53, 1.02; p-value=0.07). • There was no association between other social determinants at the county, commuting zone, state, local, and census tract levels and mass shootings.
21	(Klarevas L et al., 2019) [29] Panel study with secondary data (n=69 high-fatality mass shooting events, year 1990-2017, USA)	• To evaluate the effect of Large-capacity Magazine (LCM) bans on the frequency and lethality of high-fatality mass shootings in the US.	• Of the 69 high-fatality mass shootings, 44 involved LCM (64%), and 9 could not be determined with regard to LCM involvement (13%). • Mean number of victims in incidents involving LCM was 11.8, compared to 7.3 in incidents not involving LCM. • After adjusting for characteristics of the local population, LCM bans remained significantly associated with lower incidence of high-fatality mass shootings (adjusted beta=-1.283; 95% CI=-2.147, -0.420)) and number of deaths (adjusted beta=-3.660; 95% CI=-5.695, -1.624)).
22	(Kwon R and Cabrera JF, 2019) [30] Ecological study (n=3144 counties, 1990-2015, USA)	• To explore the connection between income inequality and mass shootings.	• Counties with 1 SD growth of income inequality experienced more mass shootings than counties with lower inequality when defined by three or more victim casualties (IRR=1.43; 95% CI=1.24, 1.66) and more mass shootings when defined by four or more victim deaths (IRR=1.57; 95% CI=1.26, 1.96).
23	(Rees CA et al., 2019) [31] Root cause analysis (n=282 articles from 10 news sources on two school shootings, USA)	• To identify commonalities and differences between two recent school shootings.	• Of the 1408 articles on the Parkland school shooting, 201 (14.3%) reported on contributing factors. • Of the 352 articles on the Santa Fe school shooting, 81 (23.0%) reported on contributing factors. • Common environmental factors included lack of safe school, culture of mass shootings, video game and social media, home environment/firearms at home. • People factors included mental illness and the police. • Process/policy factors included laws of the states where the shootings took place, national firearm laws, and politicians. • There were no equipment/supplies factors in common between the two events. • The equipment/supplies factors in the Parkland shooting included use of an AR-15 firearm, involvement of large amount of ammunition, use of smoke bombs, number of firearms in the US, and failure of police radio. • The equipment/supplies factor in the Santa Fe shooting included father's firearms.
24	(Wintemute GJ et al., 2019) [32] Case-series (n=21 cases in which ERPOs were used to prevent mass shootings, January 2016 to August 2019, USA)	• To evaluate the implementation and effectiveness of California's ERPO statute to prevent mass shootings.	• Most subjects (19 of 21) were male, non hispanic white, with mean age of 35 years, slightly younger than the 414 persons in the source population of GVROs. • Most subjects declared intent to commit mass shooting (17 of 21), and were firearm owners (14 of 21). • A total of 52 firearms were recovered from 10 cases (data missing in seven cases). • Author presented summaries of four representative cases with different characteristics (targeting workplace, targeting school/children, medical or mental health case, and politically or socially-motivated shooting).
25	(Reeping PM et al., 2019) [33] Cross-sectional time series (n=344 mass shooting events, 1998-2014, USA)	• To determine whether restrictiveness-permissiveness of state gun laws or gun ownership are associated with mass shootings in the USA.	• A 10-unit increase in state gun law permissiveness was associated with a significantly higher rate of mass shootings (11.5%; 95% CI=4.2%, 19.3%). • A 10% increase in state gun ownership was associated with a significantly higher rate of mass shootings (35.1%; 95% CI=12.7%, 62.7%). • Similar results were produced in adjusted regression analyses and when stratified by type of mass shootings.

26	(Livingston MD et al., 2019) [34] Secondary data analysis (n=179 school shootings, year 1999-2018, US)	• To estimate the association between school/shooters/gun characteristics and school shooting severity.	• Events in the database occurred mostly in schools that taught upto 9th to 12th grade (74% of all events), where the majority of students were people of color (61%), where the age of the shooter was between 15 years to 19 years (59%). • Handgun was the most commonly used weapon (81%), followed by rifles (14%) and shotguns (12%). • Fatality occurred in 30% of all events. • The mean number of casualties was 1.99 and the mean number of fatalities was 0.7. • The strongest predictors of casualties and fatalities were the age of shooter (20 years or older vs less than 15 years), the use of two or more firearms (vs one), and the use of a rifle during the shooting (vs no use). • Casualties and fatalities were also positively associated with lower urbanicity (rural and suburb vs city), the majority of students being white (vs otherwise), and the use of a shotgun during the shooting (vs no use). • Casualties and fatalities were negatively associated with teaching upto 9th to 12th grades (vs up to 5th grade), majority of students being eligible for free or reduced-price lunch. • Presence of school resource office and the number of shooters were not associated with casualties or fatalities.
27	(Capellan JA et al., 2019) [35] Secondary data analysis (n=318 mass public shootings, year 1966-2017, USA)	• To compare the demographic, background, motivation, and pre-event and event-level behaviours across four types of mass public shooters.	• Ideologically motivated shooters tended to be the most patient, methodical, and most lethal shooters. • Disgruntled employees were driven by revenge and tended to have little time to plan and were the least lethal shooters.
28	(Cabrera JF and Kwon R, 2018) [36] Panel study (n=3144 counties, year 1990-2015, USA)	• To examine the effect of household income, as well as the interaction between inequality and income on incidence of mass shootings.	• Inequality and income both predicted mass shootings. • Counties with the highest number of mass shootings were those with high inequality and high income. • Mass shootings were also significantly associated with population density, young population, and minority population. • Mass shootings became significantly more common during 2010-2015 (vs 1990-1999).
29	(Lin PI et al., 2018) [37] Panel study (n=100 mass shootings, year 1982-2018, USA)	• To explore the time trend and relevant risk factors for mass shootings in the US.	• There was an increasing trend of mass shooting incidences over time ($p<0.001$). • None of the state-level variables could predict the rate of mass shootings. • Frequency of online media coverage and online search interest were inversely associated with interval between consecutive shootings ($p<0.001$).
30	(DiMaggio C et al., 2019) [38] Secondary data analysis (n=51 mass shooting incidents, 1966-2018, USA)	• To assess evidence for the potential effectiveness of the FAWB in prevention and controlling mass-shooting homicides in the US.	• The 51 incidents had a total of 501 fatalities. • Assault rifles accounted for 86% of mass-shooting fatalities. • Mass-shooting fatalities were 70% less likely to occur during the FAWB period (RR=0.30; 95% CI=0.22, 0.39).
31	(Brown JD and Goodin AJ, 2018) [39] Secondary data analysis (n=97 mass shooting events, year 1982-2018, USA)	• To evaluate the association between mass casualty shooting venues, types of firearms, and the age of perpetrators in the US.	• Of the 97 events, 16 were school shootings. • Of the 16 school shootings, four were committed by perpetrators younger than 18 years, four by those aged 18 years to 20 years, and eight by those aged 21 years and older. • Median age of mass shooting perpetrators was 35 years. • Median age of school shooters was 21 years. • All school shooting events included long guns. • Persons aged 18 years to 20 years perpetrated about one in eight school schoolings, but accounted for about one in three victims of school shootings. • Mental health problems were associated with 53.6% of perpetrators.
32	(Baumann ML and Teasdale B, 2018) [40] Secondary data analysis (n=745 participants, including 490 community members and 255 psychiatric patients; Pittsburg, USA)	• To assess a) whether firearm access increases the odds of interpersonal violence and/or suicidality among individuals with severe mental illness living in the community. • b) whether the increased risk is disproportionate compared to community members without disorders from the same neighborhoods.	• Among the patients, 10.2% had access to firearms, compared to 18.0% of the community participants. • Patients were more likely than community members to report interpersonal violence, although the differences were not statistically significant after adjusting for covariables (34.1% vs 18.0%, adjusted OR=1.47; 95% CI=0.88, 2.46). • Patients were significantly more likely than community members to report suicidality (43.9% vs 9.8%, Adjusted OR=2.10; 95% CI=1.21, 3.67).
33	(McPhedran S, 2020) [41] Case series (n=14 mass shooting incidents, 1964-2014, Australia)	• To examine Australian mass shooting incidents and offenders.	• Offenders were all male, mostly Caucasian. • Of the 14 mass shooting incidents, four incidents were public (no prior relationship between shooter and victims). • Most offenders experienced acute life stressors and/or chronic strains prior to the events. • Diagnosis of mental illness was relatively uncommon.
34	(Koper CS et al., 2018) [42] Secondary data analysis (n=unknown, USA)	•To investigate current levels of criminal activity with assault weapons and other high-capacity semi-automatics	• Assault weapons accounted for 2% to 12% of guns used in crime in general and 13% to 16% of guns used in murders of police. • Assault weapons were used in upto 57% of firearm mass murders.
35	(Meszaros J, 2017) [43] Secondary data analysis (n=108 cases of mass shootings with known shooters and known mental health descriptions, years 1966-2014, USA)	• To establish the effect of availability of long-term, intensive mental health treatment on firearm-related violence in the US.	• Mass shooters had lower prevalence of anxiety than general population (2.8% vs 12.3%), but higher prevalence of depression (25.0% vs 16.1%) and bipolar disorder/schizophrenia (22.2% vs 2.3%). • Increasing the number of state psychiatric hospital beds per 100,000 population is associated with lower rates of homicide (beta=-0.0461; standard error=0.0223).
36	(Kalesan B et al., 2017) [44] Cross-sectional study (n=154 school shootings, January 2013 to December 2015)	• To describe the characteristics of school shooting incidents in the USA between 2013 and 2015. • To explore whether domains of firearm and educational policies and risk factors were associated with school shooting.	• Factors associated with school shootings included. • Background check for firearm purchase. • Ammunition purchase. • Per-capita mental health expenditures. • Per-capita K-21 education expenditure. • Urbanicity. • School shootings were less likely in states with background check laws, higher mental health expenditure and K-12 education expenditures.

[Table/Fig-2]: Summary of studies pertaining to perpetration of mass shooting and their determinants (n=36 studies) [9-44].
IRR: Incidence rate ratio; CI: Confidence interval; ERPOs: Extreme risk protection orders; GVROs: Gun violence restraining orders; RR: Risk ratio; OR: Odds ratio

Level description of factors	ID number of the study		
	Positive	Negative	Neutral
Intrapersonal factors			
Health-related issues			
Mental illness (any type)	[4,9]	[35]	[32]
	[10]		
	[14]		
	[15]		
	[23]		
	[31]		
	[35]		
Psychology/Behaviours			
Interest in past mass killings	[2]		
Communication of intent	[6], [24]		
Estrangement from self	[4]		
Online radicalisation	[4]		
Substance abuse	[16]		
Video game and social media use	[23]		
Gun ownership	[1], [9]		
Personal experience			
Experience of acute life stressor	[33]		
Interpersonal factors			
Family problems	[2]		
Estrangement (from families, friends, classmates)	[4]		
History of domestic violence	[11], [16]		
History of rejection	[8]		
Being single		[16]	
Having children	[16]		
Being separated or divorced	[16]		
Home environment contains firearms	[23]		
Organisational factors			
Work and school problems	[9]		
Community factors			
Gun ownership and gun control			
State gun ownership	[25]		
Community's access to assault weapons	[34]		
Ammunition purchase	[36]		
NICS sales denial		[5]	
Social-cultural factors			
Culture of mass shootings	[23]		
Online media coverage	[29]		
Institutional social capital		[20]	
Contextual factors			
Time (more recent years)	[28], [29]		
Time (COVID-19 pandemic onset)	[7]		
Time (major public holidays or hotter seasons)	[19]		
Place (Urbanicity)	[26]		
Place (near school or Places Of Interest (POI) to children)	[18]		
Place (occurrence of previous shooting in area)		[12]	
Demographics (Income inequality)	[22], [28]		
Demographics (Population density)	[28]		
Demographics (Population median age)		[28]	
Others (Lack of safe school)	[23]		
Others (Number of state psychiatric hospitals)		[35]	
Policy factors			
State firearm laws (permissive)	[1], [25]		[3]
Background check for firearm purchase		[36]	
Requirement of permit to purchase firearms		[17]	
Federal Assault Weapons Ban (FAWB)		[13]	
Large-capacity magazine ban		[21]	
Legal/Social/Health interventions			
Emergency Protection Order (ERPO/GVRO)		[24]	
Per-capita mental health and K-12 education expenditures		[36]	

[Table/Fig-3]: Factors associated with perpetration of mass shootings in the social-ecological model.
NICS: National instant criminal background check system; COVID-19: Coronavirus disease-2019

Factors associated with mass shooting casualties: At the intrapersonal and interpersonal levels, firearm characteristics were associated with casualties [Table/Fig-4]. Shootings that involved semi-automatic or automatic firearms and the use of multiple firearms had higher mean fatalities compared to shootings that involved only handguns or a single weapon. Mass shooters who targeted women based on gender or were ideologically motivated tended to be more patient and lethal than disgruntled employees. At the organisational and community levels, most data pertained to school shootings. The presence of armed officers at schools did not appear to be preventive against casualties. At the policy level, firearm safety measures, including the FAWB and LCM ban, were associated with lower casualties at mass shootings.

Level description of factors	ID number of the study		
	Positive	Negative	Neutral
Intrapersonal factors			
Firearms-related factors			
Use of semi-automatic or automatic firearms	[14]		
Use of a rifle during shooting	[26,31]		
Use of a shotgun during shooting	[26]		
Use of two or more firearms	[26]		
Psychology/Behaviours			
Targeting women in general (no specific person as target)	[16]		
Being ideologically motivated and methodical	[27]		
Being driven by revenge as an employee		[27]	
Demographics			
Older age of school shooter	[26,31]		
Interpersonal factors			
History of domestic violence	[11]		
Organisational factors			
Presence of armed officer at school	[15]		[15,26]
School teaching upto 9th to 12th grade (vs upto younger grades)	[26]		
School with students eligible for reduced-price lunch	[26]		
Community factors			
Contextual factors			
Place (Urbanicity)		[26]	
Demographic (Caucasian-majority)	[26]		
Gun ownership and gun control			
Policy factors			
Federal Assault Weapons Ban (FAWB)		[30]	
Large-capacity magazine ban		[17,21]	

[Table/Fig-4]: Factors associated with casualties of mass shooting events in the social-ecological model.

The term "positive" refers to a factor being positively associated with the outcome (i.e., the higher the level of the factor, the higher the number of mass shooting casualties). The term "negative" refers to a factor being negatively associated with the outcome (i.e.,

the higher the level of the factor, the lower the number of mass shooting casualties). The term "neutral" indicates that a factor did not have any statistically significant association with the outcome (i.e., no association).

DISCUSSION

In the present systematic review, the author systematically reviewed factors associated with the perpetration and casualties of mass shooting events. Intrapersonal, interpersonal, organisational, community, and policy factors were identified as being associated with mass shootings. These findings are particularly relevant given the increasing frequency of mass shootings in the US. As the author used the social-ecological model to describe the factors associated with the outcomes, the discussion of the study findings should also be disaggregated according to the levels of the model.

Intrapersonal factors: At the intrapersonal level, a history of mental illness and a lack of or discontinuation of treatment were commonly mentioned factors. Other reports indicated a progression of devolving behaviours in the shooter leading upto the mass shooting event, which ultimately involved the acquisition of firearms. The event would be more fatal if it involved semi-automatic firearms or shotguns. However, it is important to refrain from stigmatising individuals with mental illnesses or estrangement behaviours, as the vast majority of the nearly 53 million adults with mental illness in the US do not have plans to harm others, especially on a massive scale [45]. The study findings should only be used as an attempt to understand the phenomenon in a complete manner.

Interpersonal level: Problems in interpersonal relationships seemed to be a recurring theme in the perpetration of mass shootings. Family problems, including domestic violence, separation, or divorce, and rejection from others, were common among mass shooters. Domestic violence was also associated with the lethality of mass shootings. Considering that mental health problems are associated with family/relationship issues [10] and that family/relationship issues can lead to mental health problems [46], it is not possible to ascertain whether a variable was a risk factor or a pathway variable between another risk factor and the outcomes.

Organisational level: Perpetration of mass shootings was associated with work or school problems. Further investigation is recommended to understand the extent to which management practices or policies of the workplace or school contribute to these problems, which in turn contribute to the perpetration of mass shootings. Concerningly, the presence of armed police officers at schools had the opposite effect of what was intended, with no reduction or even an actual increase in casualties at school shooting events. Data from another source [47] showed that weapons-related arrests accounted for only 0.1% to 0.2% of all arrests made by school resource officers (school police officers), and the majority were for disorderly conduct that unnecessarily funneled students into the juvenile justice system. Given the consistency of the evidence, relevant stakeholders should reconsider the presence of armed guards or police officers in schools.

Community level: Factors at the community level appeared to be coherent and complementary to the factors identified at other levels. There were variations in mass shootings with regards to time, place, and demographics of the shooting locations. Associations between the perpetration and casualties of mass shootings were also clear: states with higher gun ownership and access to assault weapons and ammunition had higher incidents of mass shootings compared to states that were less permissive of firearms. With such clear patterns of association, local government and community leaders should consider increasing firearm safety measures where possible.

Policy level: There were clear patterns of association between firearm safety measures and the perpetration and casualties of mass shootings. In particular, the FAWB and LCM ban had negative associations with both the perpetration and casualties of mass shootings. Considering that more lethal shootings tended to involve the use of assault weapons with a higher number of ammunitions [34,39], these policies seemed to directly address these issues. Similarly, other preventive measures such as the emergency protection order and mental health expenditures were also negatively associated with the perpetration of mass shootings, suggesting that other measures should also be adopted concurrently with firearm safety laws.

A relatively new aspect of this review was the inclusion of the social-ecological model to consider mass shootings in a more holistic and systematic manner. Discussion remarks for organisational, community, and policy level factors may have direct policy implications.

Limitation(s)

A number of limitations should be considered in the findings of the present review. Firstly, the author included only manuscripts published since 2017, which is an arbitrary starting point. Systematic reviews conducted under a different approach could have yielded different results. Secondly, the level in the social-ecological model to which each potential determinant belonged was relatively subjective and based on the author's own judgement. Findings from other authors could have differed from those presented by the author. In the present review, the risks of bias and reporting bias were not seen, and hence more studies should be conducted in the future considering this aspect.

CONCLUSION(S)

In the present study, the author reviewed factors associated with the perpetration and casualties of mass shootings using the social-ecological model. Gun ownership and access to firearms were associated with the perpetration of mass shootings, whereas use of high-powered firearms and the number of firearms were associated with casualties at various levels of the social-ecological model. However, caveats including a limited time frame, limited sources of publications, and subjectivity in building the social-ecological model should be considered in the interpretation of the study findings.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Nov 26, 2023
- Manual Googling: Mar 22, 2023
- iThenticate Software: Aug 05, 2023 (16%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? NA
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Nov 23, 2022**
Date of Peer Review: **Mar 15, 2023**
Date of Acceptance: **Aug 08, 2023**
Date of Publishing: **Oct 01, 2023**