Review

Pre-Existing Medical Conditions: A Systematic Literature Review of a Silent Contributor to Adult Drowning

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Abstract: Medical conditions can increase drowning risk. No prior study has systematically reviewed the published evidence globally regarding medical conditions and drowning risk for adults. MEDLINE (Ovid), PubMed, EMBASE, Scopus, PsycINFO (ProQuest) and SPORTDiscus databases were searched for original research published between 1 January 2005 and 31 October 2021 that reported adult (≥15 years) fatal or non-fatal drowning of all intents and pre-existing medical conditions. Conditions were grouped into the relevant International Classifications of Diseases (ICD) codes. Eighty-three studies were included (85.5% high-income countries; 38.6% East Asia and Pacific region; 75.9% evidence level III-3). Diseases of the nervous system (n = 32 studies; 38.6%), mental and behavioural conditions (n = 31; 37.3%) and diseases of the circulatory system (n = 25; 30.1%) were the most common categories of conditions. Epilepsy was found to increase the relative risk of drowning by 3.8 to 82 times, with suggested preventive approaches regarding supervised bathing or showering. Drowning is a common suicide method for those with schizophrenia, psychotic disorders and dementia. Review findings indicate people with pre-existing medical conditions drown, yet relatively few studies have documented the risk. There is a need for further population-level research to more accurately quantify drowning risk for pre-existing medical conditions in adults, as well as implementing and evaluating population-level attributable risk and prevention strategies.

Keywords: pre-existing medical condition; drown; epilepsy; cardiac; injury; suicide; dementia; depression; ischaemic heart disease; seizure

1. Introduction

Drowning has been described as an underexplored threat to public health [1]. Drowning, the process of experiencing respiratory impairment due to immersion or submersion in liquid, has both fatal and non-fatal outcomes, with or without morbidity [2]. Drowning may also be unintentional, intentional or of undetermined intent. Unintentional drowning alone was estimated to claim the lives of 295,000 people around the world in 2017, with the true estimate likely to be significantly higher with the inclusion of transportation and disaster-related drowning [3]. Though less is known about drowning due to intentional self-harm [4,5], many countries also report high drowning rates due to suicide [6–8].

Chronic medical conditions are becoming more common [9]. This phenomenon affects low and high-income countries alike. Research on unintentional drowning risk among children has identified epilepsy [10,11] and autism spectrum disorder as conditions posing an increased risk of drowning [12–14]. Several studies have explored the role of chronic disease on drowning risk among older people—an age group of growing concern with respect to drowning due to an aging population [15,16]. Studies among the elderly population have highlighted the risk for drowning of conditions such as dementia, sarcopenia,
epilepsy, cardiac conditions and depression [5,11,17–20]. However, little is known regarding the drowning risk associated with pre-existing medical conditions and the interventions recommended to reduce this risk.

To date, no study has systematically reviewed the literature to examine the role of pre-existing medical conditions on adult drowning risk. This review will address the following research questions concerning the link between pre-existing medical conditions, drowning and drowning risk:

1. Which pre-existing medical conditions have been reported in adult (aged 15 years and older) drowning cases?
2. Which pre-existing medical conditions does the literature suggest impact the risk of drowning?
3. In which population(s) do pre-existing medical conditions increase drowning risk and burden?
4. What drowning reduction strategies are recommended in the literature?

2. Materials and Methods

A systematic review of peer-reviewed literature was undertaken to identify and critically analyse studies reporting drowning and chronic medical conditions in adults (aged 15 years and older) and was prospectively registered with PROSPERO (#CRD42020190605). The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [21]. From the search results, the PRISMA statement was used to identify, screen and determine eligibility for the included studies.

Peer-reviewed literature published in English between 1 January 2005 and 31 October 2021 was identified from searches of MEDLINE (OVID), PubMed, EMBASE, Scopus, PsycINFO (ProQuest) and SPORTDiscus databases. Search terms were intentionally broad, and no qualification of methodology or publication type was applied in the first search to capture all relevant article sets. Search terms included “drown*”, “adult”, “medical”, “disease” and various medical conditions. Where possible, terms and medical conditions were mapped to MESH terms. The Boolean search strings utilised for this study are described in Appendix A.

Literature was limited to a publication date of 2005, as this was the year the current drowning definition was established [2]. Studies of human drowning and chronic medical conditions were included regardless of outcome (fatal or non-fatal) and intent (unintentional, intentional self-harm, undetermined intent). Non-fatal drowning was defined in line with the Non-Fatal Drowning Categorisation Framework (NDCF) [22]. The full inclusion and exclusion criteria for the study are displayed in Table 1. Studies were included where data could be extracted for pre-existing medical conditions for people aged 15 years and older. Medical conditions were included if there was a history of the condition for the person who drowned, even if the condition was not indicated at autopsy. Conditions noted at autopsy but unknown at the time of the drowning incident were also included. Studies were excluded if they only reported acute conditions (e.g., a broken bone during the drowning incident). Case reports were included if they contained data for six or more drowning cases, regardless of the presence of a pre-existing medical condition. (Table 1).

Using Covidence literature screening software, the independent dual screening of title and abstract was undertaken, with conflicts resolved via consensus between the two reviewers. The process was repeated for the full-text review. Data were extracted using a custom-built Microsoft Excel spreadsheet. Data extracted included age group and number of participants, number of drowning incidents including by intent and outcome, study type, name of medical condition(s), number, proportion and/or rate of those who drowned with medical condition and statistical measure of risk (i.e., Chi-square tests of independence, relative risk, odds ratio). Medical conditions were identified by extracting key medical findings (i.e., medical condition, pathophysiology findings) presented in the literature. Specific medical conditions were coded to the relevant category within the International Classification of Diseases (ICD) 10 category [23]. The categories and examples of conditions
coded to each category taken from included studies are shown in Table 2. For the top three most common groups of conditions, the specific conditions within the groupings were further categorised as depicted in Table 2 [24,25]. Where studies did not report on a specific medical condition, these were coded to a grouping called “all pre-existing medical conditions”.

### Table 1. Inclusion and exclusion criteria.

| Inclusion                                                                 | Exclusion                                      |
|--------------------------------------------------------------------------|------------------------------------------------|
| Peer-review literature, 1 January 2005 to 31 October 2021, English, global | Outside date range, non-English language, non-peer-reviewed |
| Limited to humans                                                        | Non-human                                      |
| Primary research                                                         | Protocols, literature reviews                  |
| Intentional self-harm drowning                                           | -                                              |
| Data from primary analytical studies that include an unintentional drowning or submersion in water AND a medical condition (physiological or psychological) of any description. | Acute conditions such as recent musculoskeletal injuries were excluded (i.e., broken arm during experience due to the drowning event) |
| Recreational drowning and commercial sub-populations (i.e., fisherman)   | -                                              |
| Medical conditions could be known or unknown by the drowning victim prior to the drowning event (i.e., undiagnosed cardiac arrhythmia or epilepsy) | Conditions which were not chronic in nature or occurred as a result of the drowning incident (i.e., pulmonary oedema). |
| Sample comprised of adult population only or a minimum of 75% of sample | Study population aged 0–14 years only, or population aged 15 years or over could not be disaggregated |
| or age group could be easily extracted from main data set of relevant studies |                                                    |
| Case reports included if reports ≥ 6 cases and include a population and provides some indication of risk | Studies reporting < 6 cases. |

### Table 2. Medical condition groupings and examples of included conditions.

| Medical Condition Group | Sub-Categorisation | Examples of Included Conditions |
|-------------------------|--------------------|---------------------------------|
| Diseases of the circulatory system | Aneurysm and dissections | Aortic aneurysm and dissection |
|                          | Atherosclerosis     | Atherosclerosis                  |
|                          | Congenital Heart Disease | Congenital coronary arterial anomaly |
|                          | Heart Arrhythmias   | Cardiac arrhythmia, Long QT, Cardiac channel mutation, Syncope/Other, Wolf-Parkinson White Syndrome |
|                          | Hypertensive Heart Disease | Heart hypertrophy, Left Ventricle Hypertrophy |
|                          | Ischemic Heart Disease | Presence of cardio and vascular implants and grafts, blood pressure problems |
|                          | Hypertensive Vascular Disease | Coronary artery atherosclerosis; Ischaemic heart disease, coronary artery stenosis, recent myocardial infarction |
| Diseases of the digestive system | Digestive disease | Digestive disease |
| Diseases of the ear and mastoid | Hearing impairment | Hearing impairment |
| Diseases of the eye and adnexa | Blindness; low vision; visual impairment | Blindness; low vision; visual impairment |
| Diseases of the musculoskeletal system and connective tissue | Kidney dysfunction | Kidney dysfunction |
| | Physical disability | Physical disability |
| Medical Condition Group | Sub-Categorisation | Examples of Included Conditions |
|-------------------------|--------------------|---------------------------------|
| Diseases of the nervous system | Dementia | Dementia |
|                          | Seizure disorders | Convulsive epilepsy; epilepsy |
|                          | Neurological mobility disorders | Mobility disturbance; Parkinson’s Disease |
|                          | Other | Disability of brain lesion; central nervous system disease; nervous disease |
|                          | Nervous system (no further breakdown) | |
| Diseases of the respiratory system | Asthma | Asthma; respiratory disease |
| Endocrine, nutritional, and metabolic diseases | Diabetes | Diabetes; dyslipidemia; obese; overweight; underweight |
| Mental and behavioural conditions | Anxiety Disorder | Anxiety disorder |
|                                  | Behavioural Disorder | Somatic disorders, somatic comorbidity, behavioural syndromes associated with psychological disturbances and physical factors |
|                                  | Cognitive Function | Intellectual disability, mental retardation, senile dementia, disorders of psychological development, organic brain disorders |
|                                  | Mood Disorder | Depression, bipolar disorder, affective disorder, depressive disorders |
|                                  | Personality Disorder | Personality disorder |
|                                  | Psychosexual disorders | Psychosexual disorders |
|                                  | Psychotic Disorder | Psychiatric disorders, schizophrenia, non-organic psychotic disorder, neurotic disorders |
|                                  | Substance Abuse Disorders | Alcoholism, drug dependence, poisoning |
|                                  | Other Disorders | Other disorders (organic disorders) |
| Neoplasms | Cancer | |
| Symptoms, signs and conditions not elsewhere classified | Pregnancy | |

Risk factors were defined if statistical tests identified a significant link between the medical condition and risk of drowning or drowning outcome (i.e., Chi-square tests of significance, odds ratio, relative risk). Prevention strategies were extracted as free text if proposed, implemented and/or evaluated specific to drowning. Prevention strategies were coded as primary, secondary or tertiary prevention [26] and against the corresponding level within the Hierarchy of Control [27]. Quality of evidence was also assessed using the National Health and Medical Research Council (Australia) Levels of Evidence [28]. Levels of evidence range from Level I (a systematic review of Level II studies (randomised controlled trial)) to Level IV (case studies with either post-test or pre-test/post-test outcomes). Region and income levels of countries represented in included studies were assessed using the World Bank open data country profiles [29].

3. Results

Initial searches identified 5762 studies. After the removal of 1834 duplicates, a total of 3928 studies were screened at the title and abstract stage. After the removal of studies not meeting the inclusion criteria, 738 full-text studies were assessed for eligibility. Following a full text review, 83 studies were included for data extraction (Figure 1).

Included studies predominately reported data from high-income countries (n = 71; 85.5%). The largest numbers of included studies were from the World Bank region groupings East Asia and the Pacific (n = 32; 38.6%) and Europe and Central Asia (n = 28; 33.7%). The majority of the included studies were assessed at a level of evidence of III-3 (n = 63; 75.9%). There were 48 studies (57.8%) that reported unintentional drowning, and 79 (95.2%) reporting fatal drowning. The study characteristics of the full list of included studies can be found in Appendix B.
With respect to grouped medical conditions, diseases of the nervous system \([7,11,19,20,30–57]\) and mental and behavioural conditions \([7,37,42,43,54,56–82]\) were the most commonly reported categories of medical conditions in drowning, identified in 32 studies (38.6\%) and 31 studies (37.3\%), respectively. This was followed by diseases of the circulatory system \((n = 25\) studies; 30.1\% of all included studies) \([19,43,46,49,53–55,57,63,76,83–98]\) (Table 3).

![Figure 1. PRISMA flow chart.](image)

Table 3. Grouped medical condition by included studies.

| Medical Condition Grouped                              | Number of Studies | % of All Included Studies \((n = 83)\) | Reference(s)                          |
|--------------------------------------------------------|-------------------|--------------------------------------|----------------------------------------|
| Diseases of the circulatory system                     | 25                | 30.1                                 | \([19,43,46,49,53–55,57,63,76,83–98]\) |
| Diseases of the digestive system                       | 1                 | 1.2                                  | \([53]\)                               |
| Diseases of the ear and mastoid                        | 1                 | 1.2                                  | \([42]\)                               |
| Diseases of the eye and adnexa                         | 2                 | 2.4                                  | \([42,99]\)                            |
| Diseases of the genito-urinary system                  | 2                 | 2.4                                  | \([42,53]\)                            |
| Diseases of the musculoskeletal system and connective tissue | 3                 | 3.6                                  | \([19,42,100]\)                        |
| Diseases of the nervous system                         | 32                | 38.6                                 | \([7,11,19,20,30–57]\)                |
| Diseases of the respiratory system                     | 5                 | 6.0                                  | \([42,43,53,54,76]\)                  |
| Endocrine, nutritional, and metabolic diseases         | 6                 | 7.2                                  | \([11,53,56,63,76,101]\)              |
| Mental and behavioural conditions                      | 31                | 37.3                                 | \([7,37,42,43,54,56–82]\)             |
| Neoplasms                                              | 2                 | 2.4                                  | \([53,80]\)                            |
| Symptoms, signs, and conditions not elsewhere classified| 1                 | 1.2                                  | \([102]\)                              |

Note: some papers included more than one medical condition, hence the total adds to more than the total number of included studies (83).

There were 13 studies that reported all pre-existing medical conditions \([7,43,49,53,63,69,98,103–108]\). The proportion of drowning involving pre-existing medical conditions ranged from 2.8\% with chronic illness among fatal land motor vehicle drownings in Finland \([106]\) to 24.6\% of elderly (defined as 65 years and over) drowning patients in South Korea (fatal and non-fatal) reporting chronic illness (such as diabetes, hypertension and hepatitis) \([69]\). In the South Korean study, a significantly higher \((p < 0.001)\) of elderly patients had chronic disease (24.6\%) compared with the rest of the adult population who drowned (3.3\%) \([69]\). A total population study of unintentional drowning fatalities in Canada identified that 67.3\% of all adults 65+ years reported one or more
accompanying chronic conditions [98]. Pre-existing medical conditions were also prevalent in a study of intentional drowning death in Australia, found in 83.1% of deaths [7].

Seizure disorders (including epilepsy) were the most commonly reported condition within the diseases of the nervous system category, reported in 23 studies [11,19,20,30,32–35,37–40,43–47,49,52–56]. Epilepsy was found to occur in 11% of sudden deaths in hot bath tubs in Japan [20] and 9.6% of adult unintentional fatal drownings in Bangladesh [37]. Among those with epilepsy, drowning accounted for 83.3% of accidental injury deaths in Bangladesh [44] yet just 0.05% of seizure-related fatal unintentional injuries in Thailand [38] and 0.4% of hospitalised epilepsy deaths in the USA [39].

Almost half (49.1%) of all people in Portugal and the United Kingdom (UK) surveyed with Parkinson's Disease reported having experienced a non-fatal drowning [48]. Drowning deaths of people with dementia who die after going missing or wandering span from 11.3% to 42.1% [36,51] (Table 4).

Within the mental and behavioural conditions category, psychotic disorders (n = 15 studies) and mood disorders (n = 13 studies) were the two most commonly reported types of conditions implicated in cases of drowning. Drowning accounted for 9% of suicidal deaths in patients with schizophrenia in Taiwan [74]. Among those with psychotic disorders, drowning deaths varied from a high of 20.9% among people with personality disorders in Sweden [60] to a low of 1.3% of intentional drowning deaths in Australia [7]. Forty percent of psychiatric patients who died by suicide in South Korea drowned with psychotic disorders [75]. Psychotic disorders were present in 27.2% of patients who died from intentional drowning within one year of contact with mental health services in the UK [65].

Mood disorders (including bipolar and depression) were present in 61.3% of drowning deaths (both intentional and unintentional) in the Madurai region of India [79] and in 45.0% of intentional fatal drowning among psychiatric patients who suicided in South Korea [75]. A further eight studies reported substance abuse disorders. It should be noted that substance use disorders were present in 75.3% of suicidal drowning deaths in Australia [64] and 15.6% of drowning deaths in France [76] (Table 5).

Heart arrhythmias (or related conditions) were the most commonly reported condition within the diseases of the circulatory system category, reported in eight studies [19,63,83,84,86,91,95,96]. Heart arrhythmias were present in 22.9% of “unexplained” drowning deaths referred for a cardiac channel molecular autopsy in the USA [91] and 22.2% of diving-related drowning fatalities in Australia [95]. Among older people, heart arrhythmias were present in 21.7% of bathtub drownings among people aged 65+ years in Canada [63] and 15.6% of the same cohort in Australia [19].

Ischaemic heart disease was identified in five included studies [53,55,85,89,90]. Two studies were from Greece, finding that ischaemic heart disease was present in 87.9% [85] and 51.8% of drowning deaths, respectively [89]. Two other studies reporting bath-related deaths found that ischaemic heart disease was present in 34.2% of bath-related deaths in Japan [53] and 73.7% in South Korea [55].

Among other circulatory system conditions, hypertensive heart disease was present in 66.7% of drowning deaths among those competing in triathlons in the USA [83,84], and atherosclerosis was found in 20% of those who drowned with a pre-existing medical condition in Greece [85] (Table 6).
Table 4. Studies reporting conditions within the diseases of the nervous system category.

| Condition                                | Reference                          | Country    | Study Population                           | Age Group | Intent | Outcome | % Who Drowned | % Who Drowned with Med Conditions | % Who Drowned with Condition |
|------------------------------------------|------------------------------------|------------|--------------------------------------------|-----------|--------|----------|---------------|-----------------------------------|-----------------------------|
| Dementia                                 | Furumiya et al., 2015 [36]         | Japan      | Outdoor wandering deaths                   | 70–94 years | U,F    | -        | 42.1%         | -                                | -                            |
|                                          | Kikuchi et al., 2019 [41]         | Japan      | Wandering deaths among those with dementia | All ages   | U,F    | -        | 11.3%         | -                                | -                            |
|                                          | Purandare et al., 2009 [50]       | UK         | Suicide among those with dementia          | 65+ years  | I,F    | -        | 17.8%         | -                                | -                            |
|                                          | Rowe et al., 2011 [51]            | USA        | Persons with dementia who go missing       | 40–95 years| U,F    | -        | 11.4%         | -                                | -                            |
| Dementia                                 | Bain et al., 2018 [11]            | Canada     | Epilepsy or seizure with suspicion of drowning | 12–68 years| U,F    | -        | 100.0%        | -                                | -                            |
| Seizure disorders                        | Barooni et al., 2007 [30]         | Canada     | Epilepsy drowning deaths                    | 0–90 years | U,F    | -        | 0.3%          | 100%                             | -                            |
| Seizure disorders                        | Chang et al., 2012 [33]           | Taiwan     | Deaths in those with epilepsy              | All ages   | U,F    | -        | 0.21*         | -                                | -                            |
| Seizure disorders                        | Chang et al., 2014 [32]           | USA        | Epilepsy on death certificates              | All ages   | U,F    | -        | 2.7%          | -                                | -                            |
| Seizure disorders                        | Cihan et al., 2018 [34]           | USA        | Epilepsy deaths in water                    | 20–73 years| U,F    | -        | 1.4%          | -                                | -                            |
| Seizure disorders                        | Ding et al., 2013 [35]            | China      | Epilepsy diagnosis follow-up               | 10–69 years| U,L,Ind| F        | 9.6%          | -                                | -                            |
| Seizure disorders                        | Hossain et al., 2017 [37]         | Bangladesh | Adult drowning                             | 18+ years  | U,F    | -        | 0.05%         | -                                | -                            |
| Seizure disorders                        | Jinda et al., 2019 [38]           | Thailand   | Seizure related injuries                   | 15+ years  | U,F    | -        | 0.2%          | -                                | -                            |
| Seizure disorders                        | Chang et al., 2012 [33]           | Taiwan     | Deaths in those with epilepsy              | All ages   | U,F    | -        | 0.2%          | -                                | -                            |
| Seizure disorders                        | Chang et al., 2014 [32]           | USA        | Epilepsy on death certificates              | All ages   | U,F    | -        | 2.7%          | -                                | -                            |
| Seizure disorders                        | Okuda et al., 2015 [49]           | USA        | Deaths in bathtubs                         | 22–96 year | U,I,F  | -        | 18.8%         | -                                | -                            |
| Seizure disorders                        | Okuda et al., 2015 [49]           | USA        | Deaths in bathtubs                         | 65+ years  | U,F    | -        | 7.7%          | -                                | -                            |
| Seizure disorders                        | Satoshi et al., 2013 [50]         | Japan      | Sudden deaths in hot bathtubs              | 8–95 years | U,F    | -        | 11.1%         | -                                | -                            |
| Seizure disorders                        | Sillanpaa et al., 2010 [52]       | Finland    | Long term mortality among those with childhood-onset epilepsy | 1–50 years | U,F    | -        | 2.4%          | -                                | -                            |
| Seizure disorders                        | Suzuki et al., 2015 [53]          | Japan      | Autopsied bath related deaths              | All ages   | U,F    | -        | 2.8%          | -                                | -                            |
| Seizure disorders                        | Tellier et al., 2019 [54]         | France     | Drowning victims against Gironde surf beaches | All ages   | U,F    | -        | 2.0%          | -                                | -                            |
| Seizure disorders                        | Yang et al., 2018 [55]            | South Korea| Bath-related deaths                        | 18–91 years| U,F    | -        | 4.0%          | -                                | -                            |
| Seizure disorders                        | Youn et al., 2009 [56]            | South Korea| OHCA due to drowning admitted to hospital  | 3–87 years | U,L,Ind| F        | 14.3          | -                                | -                            |
| Neurological mobility disorders          | Neves et al., 2020 [48]           | Portugal & the UK | Patients with Parkinson’s Disease | M = 64 years | U,NF  | -        | 49.1%         | -                                | -                            |
| Neurological mobility disorders          | Satoh et al., 2013 [50]           | Japan      | Sudden deaths in hot bathtubs              | 8–95 years | U,F    | -        | 11.1%         | -                                | -                            |
Table 4. Cont.

| Condition | Reference | Country | Study Population | Age Group | Intent | Outcome | % Who Drowned | % Who Drowned with Med Conditions |
|-----------|-----------|---------|------------------|-----------|--------|---------|--------------|-----------------------------------|
| Other     | Kim et al., 2021 [42] | South Korea | Deaths of people with a disability | All ages | U | F | - | 4.4/100,000 * |
|           | Okuda et al., 2015 [49] | USA | Deaths in bathtubs | 22–96 year | UJ | F | - | 9.4% |
|           | Suzuki et al., 2015 [53] | Japan | Autopsied bath related deaths | All ages | U | F | 1.1% | - |
|           | Yang et al., 2018 [55] | South Korea | Bath-related deaths | 18–91 years | U | F | 5.3% | 6.0% |
| Nervous system | Cenderadewi et al., 2019 [7] | Australia | Intentional drowning deaths | All ages | I | F | 2.4% | - |
| (no further breakdown) | Feden et al., 2016 [57] | Australia | River drowning deaths | All ages | U | F | 1.7% | 4.4% |

Abbreviations: F = Fatal; I = Intentional; M = mean age; NF = Non-Fatal; OHCA = Out of Hospital Cardiac Arrest; SUDEP = Sudden Unexpected Death in Epilepsy; U = Unintentional; UK = United Kingdom; Und = Undetermined; USA = United States of America; * represents crude mortality rate per 100,000 population not proportion.

Table 5. Studies reporting conditions within the mental and behavioural conditions category.

| Condition | Reference | Country | Study Population | Age Group | Intent | Outcome | % Who Drowned | % Who Drowned with Med Conditions |
|-----------|-----------|---------|------------------|-----------|--------|---------|--------------|-----------------------------------|
| Anxiety disorder | Ahlm et al., 2015 [59] | Sweden | All drowning deaths in Sweden | 16–85 years | I | F | 0.8% | - |
|           | Cenderadewi et al., 2019 [7] | Australia | All drowning deaths | 15–64 years | I | F | 2.2% | - |
|           | Fang et al., 2015 [61] | China | Individuals with psychiatric disorder who committed suicide by drowning | 10–89 years | I | F | 1.9% | - |
| Behavioural disorder | Bjorkenstam et al., 2016 [60] | Sweden | Total population with personality disorders and/or suicidal ideation | 15–64 years | I | F | 1.1% | - |
|           | Ljusic et al., 2018 [70] | Serbia | Deaths among those with mental disorders, somatic disorders or no registered disorder | - | I | F | 14.1% | 100% |
| Cognitive function | Bjorkenstam et al., 2016 [60] | Sweden | Total population with personality disorders and/or suicidal ideation | 15–64 years | I | F | 2.2% | - |
|           | Fang et al., 2015 [61] | China | All suicide after first lifetime psychiatric hospitalisation for depression | 10–89 years | I | F | 9.7% | - |
| Mood disorder | Kim et al., 2021 [42] | South Korea | Deaths of people with a disability | All ages | U | F | 3.0% | - |
|           | Aaltonen et al., 2019 [58] | Finland | All suicide after first lifetime psychiatric hospitalisation for depression | 18+ years | I | F | 7.4% | - |
|           | Ahlm et al., 2015 [59] | Sweden | All drowning deaths in Sweden | 16–85 years | I | F | 9.5% | - |
|           | Bjorkenstam et al., 2016 [60] | Sweden | Total population with personality disorders and suicidal ideation | 15–64 years | I | F | 31.9% | - |
|           | Cenderadewi et al., 2019 [7] | Australia | All suicide after first lifetime psychiatric hospitalisation for depression | 15–64 years | I | F | 20.2% | - |
|           | Fang et al., 2015 [61] | China | All suicide after first lifetime psychiatric hospitalisation for depression | 10–89 years | I | F | 64.5% | - |
|           | Hunt et al., 2006 [65] | UK | Suicide with recent contacts with mental health services | 0–75+ years | I | F | 49.0% | - |
|           | Lee et al., 2019 [69] | South Korea | Fatal drowning | 18+ years | I | F | 18.7% | - |
|           | Maity et al., 2020 [71] | India | Drowning deaths | 0–70 years | U | F | 4.9% | - |
| Condition | Reference | Country | Study Population                                                                 | Age Group    | Intent | Outcome | % Who Drowned with Med Conditions | % Who Drowned with Condition |
|-----------|-----------|---------|-----------------------------------------------------------------------------------|--------------|--------|---------|-------------------------------|-----------------------------|
| Nishida et al., 2015 [73] | Japan | Patients diagnosed with early post stroke depression who died | 65–94 years | I | F | 70.8% | - | - |
| Park et al., 2013 [75] | South Korea | Psychiatric patients who suicide | 10+ years | I | F | 45.0% | - | - |
| Runeson et al., 2010 [77] | Sweden | Completed suicides among those treated for attempted suicide | 10+ years | I | F | 28.1% | - | - |
| Schaffer et al., 2014 [78] | Canada | Suicide in bipolar disorder | All ages | I | F | - | - | 2.9% |
| Selveraj et al., 2020 [79] | India | Drowning in Madurai Region | All ages | I | F | - | - | 61.3% |
| Personality disorder | Bjorkenstam et al., 2016 [60] | Sweden | Total population with personality disorders Sweden | 15–64 years | I | F | - | 100.0% | - |
| Hunt et al., 2006 [65] | UK | Suicide with recent (within 1 year) contact with mental health services | All ages | I | F | 100.0% | - | - |
| Psychosexual disorder | Fang et al., 2015 [61] | China | Individuals with psychiatric disorder who committed suicide by drowning | 10–89 years | I | F | - | 1.0% | - |
| Ahlm et al., 2015 [59] | Sweden | All drowning deaths in Sweden | 16–85 years | I | F | 4.2% | - | - |
| Bjorkenstam et al., 2016 [60] | Sweden | Total population with personality disorders Sweden | 15–64 years | I | F | - | 20.9% | - |
| Cenderadewi et al., 2019 [7] | Australia | Intentional drowning deaths | All ages | I | F | 4.3% | - | - |
| Fang et al., 2015 [61] | China | Individuals with psychiatric disorder who committed suicide by drowning | 10–89 years | I | F | - | 20.2% | - |
| Flaig et al., 2013 [62] | Germany | Non-natural death cases autopsied | 18–96 years | I | F | 9.0% | - | - |
| Haines et al., 2010 [64] | Australia | Completed suicides | 10–43 years | I | F | 80.6% | - | - |
| Hunt et al., 2006 [65] | UK | Suicide with recent (within 1 year) contact with mental health services | All ages | I | F | 27.2% | - | - |
| Kumar et al., 2018 [72] | India | Attempted suicides in psychiatric consultation | 10–50 years | I | NF | - | 5% | - |
| Lee et al., 2019 [69] | South Korea | Fatal drowning | 18+ years | I | F | - | 7.1% | - |
| Markarian et al., 2020 [43] | France | Selected patients admitted to ICU for a drowning-related incident | 40–74 years | I | F | 16.3% | - | 16.6% |
| Pan et al., 2021 [74] | Taiwan | Suicide mortality in patients with schizophrenia | All ages | I | F | - | - | 9.0% |
| Park et al., 2013 [75] | South Korea | Psychiatric patients who suicide | 10+ years | I | F | 4.0% | - | - |
| Runeson et al., 2010 [77] | Sweden | Completed suicides among those treated for attempted suicide | 10+ years | I | F | 11.3% | - | - |
| Stemberga et al., 2010 [80] | Croatia | Suicidal drowning deaths | 25–86 years | I | F | 2.2% | - | - |
| Stephenson et al., 2020 [81] | Australia | Drowning deaths in urban section of the River Torrens | 18–76 years | I | F | 32.4% | - | - |
| Tellier et al., 2019 [54] | France | Drowning victims along Gironde surf beaches | All ages | U | F | 0.9% | - | 10.2% | - |
### Table 5. Cont.

| Condition          | Reference                          | Country       | Study Population                                      | Age Group | Intent | Outcome | % Who Drowned | % Who Drowned with Med Conditions | % Who Drowned with Condition |
|--------------------|------------------------------------|---------------|-------------------------------------------------------|-----------|--------|---------|---------------|----------------------------------|-------------------------------|
| Substance abuse disorder | Ahlm et al., 2015 [59]                | Sweden        | All drowning deaths in Sweden                          | 16–85 years | I      | F       | 1.4%          | -                               | -                             |
|                    | Bjorkenstam et al., 2016 [60]         | Sweden        | Total population with personality disorders Sweden     | 15–64 years | I      | F       | -            | -                               | -                             |
|                    | Cenderadewi et al., 2019 [7]         | Australia     | Intentional drowning deaths                            | All ages   | I      | F       | 24.9%         | 29.9%                          | -                             |
|                    | Cenderadewi et al., 2019 [7]         | Australia     | Intentional drowning deaths                            | All ages   | I      | F       | 11.1%         | 13.4%                          | -                             |
|                    | Guay et al., 2019 [63]               | Canada        | Bathtub drownings people aged 65+                     | 65+ years  | U      | F       | 3.3%          | -                               | -                             |
|                    | Hunt et al., 2006 [65]               | UK            | Suicide with recent (within 1 year) contact with mental health services | All ages | I      | F       | 11.7%         | -                               | -                             |
|                    | Reizine et al., 2021 [76]            | France        | Death after non-fatal drowning in fresh and sea water  | All ages   | U      | F       | 15.6%         | 21.0%                          | -                             |
|                    | Williams et al., 2018 [62]           | USA           | Unintentional drowning episodes, resulting in death or injury among actively serving US armed forces | All ages   | U      | F       | 7.0%          | -                               | -                             |
| Other disorders    | Ahlm et al., 2015 [59]               | Sweden        | All drowning deaths in Sweden                          | 16-85 years | I      | F       | 1.7%          | -                               | -                             |
|                    | Park et al., 2013 [75]               | South Korea   | Psychiatric patients who suicide                       | 10+ years  | I      | F       | 15.0%         | -                               | -                             |
|                    | Runeson et al., 2010 [77]            | Sweden        | Completed suicides among those treated for attempted suicide | 10+ years | I      | F       | 14.7%         | -                               | -                             |
| All mental and behavioural disorders | Ahlm et al., 2015 [59]               | Sweden        | All drowning deaths in Sweden                          | 16–85 years | I      | F       | 17.6%         | -                               | -                             |
|                    | Cenderadewi et al., 2019 [7]         | Australia     | Intentional drowning deaths                            | All ages   | I      | F       | 83.1%         | -                               | -                             |
|                    | Fang et al., 2015 [61]               | China         | Individuals with psychiatric disorder who committed suicide by drowning | 10-89 years | I      | F       | -            | 1.0%                           | -                             |
|                    | Fang et al., 2015 [61]               | China         | Individuals with psychiatric disorder who committed suicide by drowning | 10-89 years | I      | F       | -            | 2.0%                           | -                             |
|                    | Guay et al., 2019 [63]               | Canada        | Bathtub drownings people aged 65+                     | 65+ years  | U      | F       | 9.8%          | -                               | -                             |
|                    | Hussain et al., 2017 [57]            | Bangladesh    | Adult drowning                                         | 18+ years  | U      | F       | 9.9%          | -                               | -                             |
|                    | Kuchy et al., 2015 [66]              | Ireland       | Individuals who died by probable suicide               | 18+ years  | I      | F       | 23.1%         | -                               | -                             |
|                    | Kim et al., 2021 [42]                | South Korea   | Deaths of people with a disability                     | All ages   | U      | F       | -            | 7.0*                           | -                             |
|                    | Koo et al., 2021 [67]                | Australia     | Data from the Queensland Suicide Register              | 65+ years  | I      | F       | 44.6%         | -                               | -                             |
|                    | Lawes et al., 2021 [68]              | Australia     | Suicidal deaths along the Australian coast             | 18+ years  | I      | F       | 59.8%         | -                               | -                             |
|                    | Reizine et al., 2021 [76]            | France        | Death after non-fatal drowning in fresh and sea water  | All ages   | U      | F       | 26.7%         | 36.0%                          | -                             |
|                    | Stemberga et al., 2010 [80]          | Croatia       | Suicidal drowning deaths                               | 25–86 years | I      | F       | 13.4%         | -                               | -                             |

Abbreviations: F = Fatal; I = Intentional; NF = Non-Fatal; OHCA = Out of Hospital Cardiac Arrest; U = Unintentional; UK = United Kingdom; Und = Undetermined; USA = United States of America; * represents crude mortality rate not proportion.
### Table 6. Studies reporting conditions within the diseases of the circulatory system category.

| Condition                        | Reference                                      | Country      | Study Population                      | Age Group | Intent | Outcome | % Who Drowned | % Who Drowned with Med Conditions | % Who Drowned with Condition |
|----------------------------------|------------------------------------------------|--------------|---------------------------------------|-----------|--------|---------|---------------|----------------------------------|------------------------------|
| **Aneurysms and Dissections**    | Kevekidis et al., 2021 [85]                    | Greece       | Drowning deaths                       | 15–75+ years | U, F   | 0.4%    | 0.7%          | -                               | -                            |
| **Atherosclerosis**              | Kevekidis et al., 2021 [85]                    | Greece       | Drowning deaths                       | 15–75+ years | U, F   | 12.5%   | 20.0%         | -                               | -                            |
| **Cardiomyopathies**             | Kevekidis et al., 2021 [85]                    | Greece       | Drowning deaths                       | 15–75+ years | U, F   | 9.6%    | 14.1%         | -                               | -                            |
|                                  | Yang et al., 2018 [55]                         | South Korea  | Bath-related deaths                   | 18–91 years | U, F   | 1.8%    | 2.0%          | -                               | -                            |
| **Congenital heart disease**     | Harris et al., 2017 [83]                       | USA          | Sudden death during sanctioned triathlon | 15–80 years | U, F   | 11.1%   | -             | -                               | -                            |
| **Heart arrhythmias**            | Guay et al., 2019 [63]                         | Canada       | Bathtub drownings people aged 65+     | 65+ years | U, F   | 21.7%   | -             | -                               | -                            |
|                                  | Harris et al., 2010 [84]                       | USA          | Sudden death in USA Triathlon sanctioned events | -         | U, F   | 11.1%   | -             | -                               | -                            |
|                                  | Harris et al., 2017 [83]                       | New Zealand  | Breath-hold diving fatalities         | 24–70 years | U, F   | 20.7%   | -             | -                               | -                            |
|                                  | Peden et al., 2019 [19]                        | Australia    | Bathub drowning                       | 65-85+ years | U, F   | 15.6%   | 19.2%         | -                               | -                            |
|                                  | Tester et al., 2011 [91]                       | USA          | Unexplained drowning victims referred for a cardiac channel molecular autopsy | 35-60 years | U, F   | 22.9%   | -             | -                               | -                            |
|                                  | Walker et al., 2006 [95]                       | Australia    | Diving-related fatalities             | 21-81 years | U, F   | 22.2%   | -             | -                               | -                            |
|                                  | Walker et al., 2009 [96]                       | Australia    | Diving-related fatalities             | 20-65 years | U, F   | 11.1%   | -             | -                               | -                            |
| **Hypertensive heart disease**   | Harris et al., 2010 [84]                       | USA          | Competitors in USA Triathlon sanctioned events | -         | U, F   | 66.7%   | -             | -                               | -                            |
|                                  | Harris et al., 2017 [83]                       | USA          | Sudden death during sanctioned triathlon | 15–80 years | U, F   | 66.7%   | -             | -                               | -                            |
| **Hypertensive vascular disease**| Guay et al., 2019 [63]                         | Canada       | Bathtub drownings people aged 65+     | 65+ years | U, F   | 15.2%   | -             | -                               | -                            |
|                                  | Kevekidis et al., 2021 [85]                    | Greece       | Drowning deaths                      | 15–75+ years | U, F   | 2.1%    | 3.3%          | -                               | -                            |
|                                  | Schneppe et al., 2021 [90]                     | Germany      | Deaths in water                      | 1–90 years | I, U   | 14.3%   | 38.3%         | -                               | -                            |
| **Ischaemic heart disease**      | Kevekidis et al., 2021 [85]                    | Greece       | Drowning deaths                      | 15-75+ years | U, F   | 87.9%   | -             | -                               | -                            |
|                                  | Papadodima et al., 2007 [69]                   | Greece       | Drowning victims                     | <15-74+ years | U, F   | 51.8%   | -             | -                               | -                            |
|                                  | Scheppe et al., 2021 [90]                      | Germany      | Deaths in water                      | 1–90 years | I, U   | 23.0%   | 61.7%         | -                               | -                            |
|                                  | Suzuki et al., 2015 [53]                       | Japan        | Autopsied bath related deaths        | 0-90+ years | U, F   | 34.2%   | 43.2%         | -                               | -                            |
|                                  | Yang et al., 2018 [55]                         | South Korea  | Bath-related deaths                  | 18–91 years | U, F   | 73.7%   | 84.0%         | -                               | -                            |
| **All cardiovascular conditions**| Claesson et al., 2013 [97]                     | Sweden       | Swedish National Board of Forensic Medicine autopsyed drowning cases | 22-71 years | I, U, F | 10.1%   | -             | -                               | -                            |
|                                  | Guay et al., 2019 [63]                         | Canada       | Bathtub drownings people aged 65+    | 65+ years | U, F   | 6.5%    | 30.0%         | -                               | -                            |
|                                  | Harris et al., 2010 [84]                       | USA          | Competitors in USA Triathlon sanctioned events | -         | U, F   | 77.8%   | -             | -                               | -                            |
|                                  | Harris et al., 2017 [83]                       | USA          | Sudden death during sanctioned triathlon | 15–80 years | U, F   | 77.8%   | -             | -                               | -                            |
|                                  | Kevekidis et al., 2021 [85]                    | Greece       | Drowning deaths                      | 15-75+ years | U, F   | 62.5%   | -             | -                               | -                            |
|                                  | Lippmann et al. 2021 [86]                     | New Zealand  | Breath-hold diving fatalities        | 24-70 years | U, F   | 34.5%   | -             | -                               | -                            |
|                                  | Markarian et al., 2020 [43]                    | France       | Selected patients admitted to ICU for a drowning-related incident | 40-74 years | I, F   | 35.6%   | 26.0%         | -                               | -                            |
|                                  | Mishima et al., 2018 [67]                      | Japan        | Bath-related deaths                  | 34–92 years | U, F   | 24.4%   | 28.6%         | -                               | -                            |
|                                  | Morgan et al., 2008 [88]                       | Australia    | Surf beach swimmers and surfers      | 13–46 years | U, F   | 26.4%   | 87.2%         | -                               | -                            |
|                                  | Morris et al., 2016 [46]                       | South Africa | Bodies retrieved from water and immersion related deaths | 18+ years | U, F   | 4.8%    | 40.0%         | -                               | -                            |
|                                  | Okuda et al., 2015 [49]                        | USA          | Deaths in bathtub                    | 22-96 year | U, F   | 30.3%   | 62.5%         | -                               | -                            |
|                                  | Peden et al., 2016 [57]                        | Australia    | River drowning deaths                | 0-75+ years | U, F   | 5.6%    | 14.8%         | -                               | -                            |
Table 6. Cont.

| Condition | Reference | Country        | Study Population                          | Age Group | Intent | Outcome | % Who Drowned | % Who Drowned with Med Conditions | % Who Drowned with Condition |
|-----------|-----------|----------------|-------------------------------------------|-----------|--------|---------|---------------|----------------------------------|-----------------------------|
| Bathtub drownings | Peden et al., 2019 [19] | Australia | 65–85+ years | U | F | 43.8% | - | 53.8% | - |
| Death after non-fatal drowning in fresh and sea water | Reizine et al., 2021 [76] | France | M age = 68 years | I,U | F | 10.7% | - | 14.5% | - |
| Autopsied bath related deaths | Suzuki et al., 2015 [53] | Japan | 0–90+ years | U | F | 50.9% | - | 64.4% | - |
| Drowning victims along Gironde surf beaches | Tellier et al., 2019 [54] | France | 0–65+ years | U | F | 3.0% | - | 34.7% | - |
| Land motor traffic crash related drownings | Tikka et al., 2021 [92] | Finland | M age = 34.7 years | I,U | F | 9.0% | - | - | - |
| Diving-related fatalities | Vinkel et al., 2016 [84] | Denmark | 21–59 years | U | F | 20.8% | - | - | - |
| Bath-related deaths | Yang et al., 2018 [55] | South Korea | 18–91 years | U | F | - | - | 86.0% | - |

Abbreviations: F = Fatal; I = Intentional; U = Unintentional; Und = Undetermined; USA = United States of America.
There were 10 risk factors identified from the literature. These included increasing age, being at home, living near water, freshwater, medical conditions, medication (not on correct dose), sex (depending on medical condition), time of day and inpatient vs outpatient treatment (Table 7).

For epilepsy, there is an increase in the risk of drowning from between 3.8 times in the USA [39] to 82 times in China [47]. Specific to epilepsy and drowning, those with epilepsy in a study from the USA were found to be more likely to drown at home than in hospital or at a health care facility [31]; in rural China, those with epilepsy were found to have greater drowning risk if they resided in waterside areas than those living in the mountains [35], to have had epilepsy for a shorter period than those who survived [47] and to have a lower dosage of phenobarbital recorded at time of last follow up than those who survived [47].

By sex, females with personality disorders [60] and schizophrenia [74] were found to be at increased risk of suicidal drowning when compared to males; however, males were found to be at increased risk of dying from drowning with epilepsy [47]. Older age was found to be a risk factor for drowning with pre-existing medical conditions in studies of disability in South Korea (those aged 80+ years) [42], among coastal drowning fatalities in Australia [105] and for elderly patients with diabetes, hypertension and hepatitis in South Korea [69] (Table 7).

There were a total of 17 studies that discussed 26 unique strategies for preventing drowning related to pre-existing medical conditions [7,11,19,31,34,41,44,47,48,53,57,59,68,77,89,91,96]. The majority of strategies were administrative in nature when aligned to the Hierarchy of Control (n = 24; 92.3%) and all were proposed, as opposed to implemented and/or evaluated. Strategies were commonly educational in nature (n = 12 recommendations; 48.0% of all recommendations), followed by testing (n = 6; 24.0%), treatment (n = 3; 12.0%) and policy (n = 3; 12.0%) (Table 8).
### Table 7. Risk factors related to pre-existing medical conditions and drowning.

| Risk Factor          | Medical Condition                          | Note                                                                                                                                                                                                 | Reference |
|----------------------|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| Age                  | Disability                                  | Age related risk for drowning increased as people age, for example for precipitating medical factors younger (15–34 year) males were 3.7 times less likely to drown *                                          | [42]      |
|                      | Precipitating medical factors               |                                                                                                                                                                                                       | [105]     |
|                      | Chronic disease                             |                                                                                                                                                                                                       | [69]      |
| Location—home        | Epilepsy                                    | People with epilepsy/seizures were more likely to drown at home (RR = 2.35, 95% CI = 1.9–3.0, \( p < 0.001 \)) than people without epilepsy/seizures.                                                      | [31]      |
| Location—waterside areas | Epilepsy                                    | Living near water increased the risk compared to those living in the mountains (Hazard Ratio 3.9, 95% CI 1.7–9.2, \( p = 0.002 \)).                                                                       | [35]      |
| Location—Freshwater  | Mental and behavioural condition             | When comparing baseline characteristics of the patients according to the salinity of the water, freshwater drowning patients were younger and suffered more often from psychiatric comorbidities (47.9 vs. 19.1%; \( p < 0.001 \)). | [76]      |

- **Medical condition**
  - Cardiac disease
  - Cardiomegaly
  - Cardiomyopathy *
  - Chronic conditions
  - Circulatory system
  - Dementia
  - Epilepsy
  - Mental and Psychotic disorder
  - Mental and Behavioural condition
  - Schizophrenia

There were 10 medical conditions or groups of conditions that were identified as increasing the risk of drowning. Cardiac disease was found in 14% of all accidental drownings but in none (0%) in the suicide group \( p < 0.05 \). Cardiomegaly \( (p < 0.05) \) was higher among those who drowned compared to other causes of sudden or violent death. Drowning cases had significantly lower odds of presenting with cardiomyopathy \( (p < 0.001) \) than other causes of sudden or violent death. Those with chronic diseases had an OR of 15.1 compared with those who drowned without pre-existing disease. Significantly higher association of CT genotype/allele in drowned people (0.545) than controls (0.279) \( p = 0.008 \). Drowning was OR 1.55 (95%CI: 0.90–2.69) times more likely among those with dementia than healthy individuals as a suicide method. People with epilepsy drowned at a rate between 6.7–82 times greater than the general population, depending on location and age group. Patients with alcoholism more likely to die from drowning. For example, service members with any history of alcohol-related disorder were nearly twice that of those without any history of alcohol-related disorder. Compared with the general population, people with psychotic disorders were 3.28 times (95%CI: 1.16–9.26) more likely to suicide by drowning. Compared to poisoning, psychotic disorder males with a Hazard Ratio 6.2 (95%CI: 3.3 to 11.6) and females with a Hazard Ratio 9.7 (95%CI: 5.3 to 17.8) were more likely to successfully suicide by drowning. Patients diagnosed as having schizophrenia were more likely to commit suicide through drowning than the general population (odds ratio (OR) = 1.48, 95% CI = 1.27–1.73, \( p < 0.001 \)).
Table 7. Cont.

| Risk Factor | Medical Condition | Note | Reference |
|-------------|-------------------|------|-----------|
| Medication  | Epilepsy          | The dosage of phenobarbital recorded at the time of last follow-up was lower ($p < 0.001$) in the group who drowned than in those who survived. | [47] |
| Sex—female  | Personality disorders Schizophrenia | Women diagnosed with a PD had the highest SMR for drowning. Compared with schizophrenic men, schizophrenic women were more likely to suicide through drowning (23.8 cases in every 100,000 people; $p < 0.001$). | [60] [74] |
| Sex—male    | Epilepsy          | Males with epilepsy were more likely to drown than females with epilepsy ($p = 0.017$). | [47] |
| Time        | Psychotic disorders | Patients were more likely to use suicide methods other than hanging (e.g., OR = 6.7 for jumping, 5.3 for drowning and 2.7 for self-poisoning) between midnight and dawn. | [75] |
| Treatment   | Psychotic disorders | Compared with outpatients, patients who had received inpatient treatment were more likely to use drowning (OR = 3.46; 95%CI: 1.30–9.22; $p = 0.013$) than hanging. | [75] |

Abbreviations: COD = cause of death; CI = confidence interval; OR = odds ratio; PD = personality disorder; RR = Relative Risk; SMR = standardised mortality rate. * denotes lower drowning risk.

Table 8. Drowning prevention strategies documented in included literature by medical condition.

| Prevention Strategy Coded | Prevention Strategy Free Text | Medical Condition Category | Drowning Intent | Primary, Secondary or Tertiary | Proposed (P), Implemented (I) or Evaluated (E) | Hierarchy of Control | Reference |
|---------------------------|--------------------------------|-----------------------------|----------------|---------------------------------|-----------------------------------------------|---------------------|-----------|
| Education                 | Counselling regarding drowning prevention for people with epilepsy | Nervous system               | Unintentional  | Primary                         | P                                             | Administrative       | Bain et al. 2018 [11] |
| Education                 | Routinely warn people with epilepsy about the potential for drowning while bathing | Nervous system               | Unintentional  | Primary                         | P                                             | Administrative       | Bowman et al. 2010 [31] |
| Education                 | Encourage showering alternatively. Children and those who require dependent care, who may not be capable of showering, should not be left unattended in a bathtub | Nervous system               | Unintentional  | Primary                         | P                                             | Substitution         | Bowman et al. 2010 [31] |
| Education                 | Promote impact of alcohol and substance misuse | Nervous system               | Unintentional  | Primary                         | P                                             | Administrative       | Cenderadewi, 2019 [7] |
| Education                 | Supervision and specific bathing precautions could be effective prevention strategies | Nervous system               | Unintentional  | Primary                         | P                                             | Administrative       | Cihan et al., 2018 [34] |
### Table 8. Cont.

| Prevention Strategy Coded | Prevention Strategy Free Text | Medical Condition Category | Drowning Intent | Primary, Secondary or Tertiary | Proposed (P), Implemented (I) or Evaluated (E) | Hierarchy of Control | Reference |
|---------------------------|--------------------------------|-----------------------------|----------------|-------------------------------|-----------------------------------------------|---------------------|-----------|
| Education                 | Policymakers and healthcare professionals should increase public awareness that people whose families consider their cognitive function normal or normal for their age can go missing. | Nervous system               | Unintentional | Secondary                      | P                                             | Administrative      | Kikuchi et al., 2019 [41] |
| Education                 | Water safety programs for people of all ages with epilepsy, appropriate for level of ability. | Nervous system               | Unintentional | Primary                       | P                                             | Administrative      | Mateen et al., 2012 [44] |
| Education                 | Educating people with epilepsy and their carers of the risks of drowning. Alert those with Parkinson's Disease to the potential risks associated with swimming and the need to understand the disease-related features that contribute to the changes in swimming performance. | Nervous system               | Unintentional | Primary                       | P                                             | Administrative      | Neves et al., 2020 [48] |
| Education                 | Increased GP and carer awareness of role of medical conditions and bathtub drowning risk. | All pre-existing medical conditions | Unintentional | Primary                       | P                                             | Administrative      | Peden et al., 2019 [19] |
| Education                 | Showering is a safer solution especially where showering aids such as chairs are used. Family members should pay attention to elderly people who have circulatory diseases during bathing, particularly in winter. Prevention and treatment guidelines developed. | Circulatory system           | Unintentional | Primary                       | P                                             | Administrative      | Suzuki et al., 2015 [53] |
| Guidelines               | Prevent dementia patients who live alone from going missing and ensure their absence is noticed immediately. | Nervous system               | Unintentional | Primary                       | P                                             | Administrative      | Kikuchi et al., 2019 [41] |
| Policy                  | Local governments should appeal to inhabitants for cooperation with search activities. | Nervous system               | Unintentional | Secondary                     | P                                             | Administrative      | Kikuchi et al., 2019 [41] |
| Policy                  | Local governments, police stations and MESN should be prepared to initiate search activities immediately. | Nervous system               | Unintentional | Secondary                     | P                                             | Administrative      | Kikuchi et al., 2019 [41] |
| Testing                | Patients with cardiovascular disease, and particularly those with infarctions, should undergo special testing (e.g., Holter monitoring during swimming). | Circulatory system           | Unintentional | Primary                       | P                                             | Administrative      | Papadodima et al., 2007 [89] |
| Testing                | A medical check-up for those who go diving. Testing considered in post-mortem evaluation of unexplained drowning, especially if positive personal or family history is elicited to identify cardiac channel mutation. | Circulatory system           | Unintentional | Primary                       | P                                             | Administrative      | Peden et al., 2016 [57] |
| Testing (genetic)         | Testing considered in post-mortem evaluation of unexplained drowning, especially if positive personal or family history is elicited to identify cardiac channel mutation. | Circulatory system           | Unintentional | Primary                       | P                                             | Administrative      | Tester et al., 2011 [91] |
### Table 8. Cont.

| Prevention Strategy Coded | Prevention Strategy Free Text                                                                 | Medical Condition Category | Drowning Intent       | Primary, Secondary or Tertiary | Proposed (P), Implemented (I) or Evaluated (E) | Hierarchy of Control   | Reference                                      |
|---------------------------|-------------------------------------------------------------------------------------------------|----------------------------|-----------------------|--------------------------------|-----------------------------------------------|------------------------|------------------------------------------------|
| Testing                   | Over 45 years of age, divers and snorkelers should have their cardiovascular health periodically assessed by a dive doctor, preferably well aware of the cardiovascular stressors associated with diving and snorkelling | Circulatory system         | Unintentional         | Primary                        | P                                             | Administrative         | Walker et al., 2009 [96]                           |
| Training                  | Bystander rescue and CPR training                                                              | Mental and behavioural     | Intentional           | Secondary (rescue)             | P                                             | Administrative         | Cenderadewi et al. 2019 [7]                        |
| Training                  | Development of suicide-response training by surf lifesaving volunteers                          | Mental and behavioural     | Intentional           | Primary                        | P                                             | Administrative         | Lawes et al., 2021 [68]                           |
| Treatment                 | Design a comprehensive psychiatric assessment and management plan, by promoting identification, treatment and follow-up of individuals with psychiatric conditions | Mental and behavioural     | Intentional           | Primary                        | P                                             | Administrative         | Cenderadewi et al. 2019 [7]                        |
| Treatment                 | Intensified aftercare is warranted after suicide attempts                                     | Mental and behavioural     | Intentional           | Primary                        | P                                             | Administrative         | Runeson et al., 2010 [77]                          |

Abbreviations: CPR = Cardio-pulmonary Resuscitation; GP = General Practitioner; MESN = Missing Elderly Search Network.
4. Discussion

As the global population ages, the prevalence of comorbidities grows [109]. This systematic literature review shows that drowning occurs in people with pre-existing medical conditions, and that people with pre-existing medical conditions appear to be over-represented in drowning statistics. It also identified several conditions where drowning risk is heightened. Epilepsy was found to increase the relative risk of drowning by between 3.8 [39] and 82 times [47]. Risk factors for drowning in epilepsy included being of male sex [47], drowning at home [31], lower dosage of phenobarbital [47] (although it must be noted this is not a commonly used medication for seizure control/management in middle and high income country medical systems) and having a shorter duration of epilepsy [47]. Aside from seizures, other nervous system conditions, including dementia and Parkinson’s Disease, were also identified. Drowning is both a leading cause of death among those with dementia who die while wandering [36] and a common suicide method for those with dementia [50]. Parkinson’s Disease was reported to impact swimming ability leading to non-fatal drowning [48].

Mental and behavioural conditions was the second most commonly explored category of condition within the included literature. The included literature identified drowning as a popular suicide method for those with schizophrenia [74], psychotic disorders [77] and dementia [50]. Comprehensive psychiatric assessment and management and education in alcohol and substance misuse were recommended as education-based primary prevention strategies for intentional drowning involving mental and behavioural disorders, as well as bystander rescue and CPR training as secondary and tertiary measures [7]. Suicide response training for lifeguard and lifesavers has also been proposed, but not yet implemented or evaluated [68].

Diseases of the circulatory system were highlighted in 30% of included studies. Given ischaemic heart disease remains a leading cause of mortality globally [110], it is unsurprising to see cardiac conditions well represented within the drowning literature. Similarly, physical exercise such as swimming can temporarily increase the risk of aggravating cardiovascular conditions [85]. This is an important challenge, as aquatic exercise can be an effective and low-impact form of exercise, thus improving health and fitness [111]. The prevalence of unknown cardiac disease or cardiac conductivity issues during autopsy was also highlighted [63,83,86,91].

Diseases of the nervous system were also highlighted in the literature. Nervous systems disorders are wide-ranging, and this was reflected in the literature. The conditions that were highlighted appear to reflect those relating to the central nervous system and those that propagate immobility. Although aquatic exercise is often promoted to individuals with these conditions due to the non-weight bearing nature of the exercise, the risk of drowning must be considered. Levels of consciousness and mobility both pose a risk in drowning.

With this exploration of drowning and medical conditions, it was difficult to determine if there was an increased rate of drowning. For future studies, we propose that the studies include the total number of drowning deaths, the total number of people in the population, the population rate of the condition being studied and a relative risk (or similar) for drowning. This would allow future reviews to clearly be able to show the rate of drowning and the rate of drowning in the condition being explored, thus enabling a relative risk to be calculated.

One of the most common drowning prevention recommendations related to supervised bathing or the replacement of bathing with showering for those with diseases of the nervous system, such as seizure disorders [31]. Additionally, it was recommended that care givers of those with diseases of the circulatory system be aware of the drowning risks for those with such conditions, especially in the winter months [53]. For elderly adults with pre-existing medical conditions of any kind, showering with the use of an aid, such as a chair, was also recommended [19]. The majority of proposed drowning prevention encompassed primary drowning prevention strategies; however, many were administrative in nature, reflecting a low level of effectiveness on the hierarchy of control [27].
Additionally, all 25 unique drowning prevention recommendations were proposed only, identifying a knowledge gap regarding the efficacy of interventions based on implementation and evaluation.

Finally, with an aging population and increasing comorbidities comes an increased prescription medical rate, resulting in polypharmacy [112]. Multiple medications can contribute to drowning risk [113]; however, no study to date has examined the complex nature of polypharmacy, pre-existing medical conditions and adult drowning risk. This topic presents an opportunity for future research.

This study is the first to systematically explore the peer-reviewed literature to explore drowning and comorbidities and provides valuable information around conditions increasing drowning risk and research gaps. However, the findings of this study must be considered in light of some limitations. Within the included literature, we did not document if the person who drowned knew they had the particular condition or were treated appropriately for it. Only one included study reported medication levels as a risk factor, exploring phenobarbital levels among epileptics [47]. Secondly, the included studies are where drowning and a particular pre-existing medical condition co-occurred; there did not need to be, nor did we draw, a causal link between drowning and the condition in order for the study to be included in this review. Thirdly, where multiple pre-existing medical conditions are present, we did not examine the attributable drowning risk for individual conditions. All limitations also offer opportunities to strengthen the evidence base around medical conditions and drowning risk in the future.

5. Conclusions

Drowning occurs in people with existing medical conditions. This review has highlighted several pre-existing medical conditions that increase drowning risk; however, we also identified numerous research gaps. As we live longer and the proportion of the population with comorbidities increases, there is a need to better quantify the drowning risk associated with pre-existing medical conditions. Future research should include population level studies comparing disease prevalence in the general population to those who drown and better delineate the attributable risk for those with multiple medical conditions. In addition, there is a need for the implementation and evaluation of proposed strategies to reduce drowning burden and the risk associated with pre-existing medical conditions.

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### Appendix A

#### Table A1. Databases and Search Terms Used.

| Search Number | Search Term |
|---------------|-------------|
| MEDLINE (Ovid) | exp Drowning/3 |
|               | exp Water Sports/ |
|               | exp *Immersion/ |
|               | lakes/ or exp “oceans and seas”/ or ponds/ or rivers/ or dams/ |
|               | bathing beaches/or swimming pools/ |
|               | 1 or 2 or 3 or 4 or 5 |
|               | exp Death/ |
|               | exp Mortality/ |
|               | exp Morbidity/ |
|               | 7 or 8 or 9 |
|               | exp Chronic Disease/ |
|               | exp Epilepsy/ |
|               | exp Diabetes Mellitus/ |
|               | exp Mental Disorders/ |
|               | exp respiratory tract infections/or exp neoplasms/or exp musculoskeletal diseases/or exp digestive system diseases/or exp stomatognathic diseases/or exp respiratory tract diseases/or exp otorhinolaryngologic diseases/or exp nervous system diseases/or exp eye diseases/or exp male urogenital diseases/or exp “female urogenital diseases and pregnancy complications”/or exp cardiovascular diseases/or exp “hemic and lymphatic diseases”/or exp “congenital, hereditary, and neonatal diseases and abnormalities”/or exp “skin and connective tissue diseases”/or exp “nutritional and metabolic diseases”/or exp endocrine system diseases/or exp immune system diseases/or exp “disorders of environmental origin”/or exp occupational diseases/or exp chemically-induced disorders/or exp “wounds and injuries”/ |
|               | 11 or 12 or 13 or 14 or 15 |
|               | 6 and 16 |
|               | 10 and 17 |
| Search Number | Search Term |
|---------------|-------------|
| 19            | exp adult/  |
| 20            | 18 and 19   |
| 21            | limit 20 to (english language and humans and yr = “2005–2021”) |

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((drown* OR submer*) AND (death* OR mortality OR morbidity)) AND (“chronic disease*”) OR (“chronic illness*”) OR (epilep*) OR (seizure*) (arrest*) OR (cardiac*) OR (cardio*) OR (pulmon*) OR (asystole*) OR (heart*) OR (lung*) OR (diabet*) OR (respir*) OR (neoplasm*) OR (cancer*) OR (musculoskeletal*) OR (digest*) OR (stomatognathic*) OR (lymphat*) OR (vascul*) OR (congenital*) OR (hereditary*) OR (metabol*) OR (endocrin*) OR (immun*) OR (liver*) OR (arrythmia*) OR (“multiple sclerosis”) OR (motor*) OR (dementia*) OR (Alzheimer*) OR (parkinson*) OR (nervous*) OR (nerve*) OR (neuro*) OR (Amyotrophic Lateral Sclerosis*) OR (autism*) OR (addict*) OR (mental*) OR (psych*) OR (“medical condition*”) AND (humans[Filter]) AND (english[Filter]) AND (alladult[Filter]) AND (2005:2020[pdat])) Filters: Humans, English, Adult: 19+ years

((“drown*”[All Fields] OR “submer*”[All Fields]) AND (“death*”[All Fields] OR (“mortality”[MeSH Terms] OR “mortality”[All Fields]) OR “mortalities”[All Fields]) OR (“epidemiology”[MeSH Subheading]) OR “epidemiology”[All Fields]) OR “morbidity”[All Fields]) OR “chronic illness”[All Fields]) OR “epilep*”[All Fields]) OR “seizure*”[All Fields]) AND “arrest*”[All Fields]) OR “cardiac*”[All Fields]) OR “cardio*”[All Fields]) OR “pulmon*”[All Fields]) OR “asystole*”[All Fields]) OR “lung*”[All Fields]) OR “diabet*”[All Fields]) OR “neoplasm*”[All Fields]) OR “cancer*”[All Fields]) OR “musculoskeletal*”[All Fields]) OR “cardio*”[All Fields]) OR “vascul*”[All Fields]) OR “congenital*”[All Fields]) OR “hereditary*”[All Fields]) OR “metabol*”[All Fields]) OR “endocrin*”[All Fields]) OR “immun*”[All Fields]) OR “liver*”[All Fields]) OR “arrythmia*”[All Fields]) OR “lateral*”[All Fields]) OR “lateralisation”[All Fields]) OR “lateralizations”[All Fields]) OR “lateralise”[All Fields]) OR “lateralised”[All Fields]) OR “functional laterality”[MeSH Terms]) OR (“functional”[All Fields] AND “laterality”[All Fields]) OR “laterality”[All Fields]) OR “lateral”[All Fields]) OR “lateralisation”[All Fields]) OR “lateralizations”[All Fields]) OR “lateralise”[All Fields]) OR “lateralised”[All Fields]) OR “lateralizations”[All Fields]) OR “lateralize”[All Fields]) OR “lateralized”[All Fields]) OR “lateralizing”[All Fields]) OR “lateralizes”[All Fields]) OR “lateralizing”[All Fields]) OR “lateralize”[All Fields]) AND “sclerosis*”[All Fields]) OR “autism*”[All Fields]) OR “addict*”[All Fields]) OR “mental*”[All Fields]) OR “psych*”[All Fields]) OR (“medic”[All Fields] OR “medical”[All Fields]) OR “medicalization”[MeSH Terms]) OR “medicalizations”[All Fields]) OR “medicalize”[All Fields]) OR “medicalized”[All Fields]) OR “medicals”[All Fields]) OR “medications”[All Fields]) OR “medically”[All Fields]) OR “medications”[All Fields]) OR “medicated”[All Fields]) OR “medication”[All Fields]) OR “medication”[All Fields]) OR “medication”[All Fields]) OR “medications”[All Fields]) AND “condition”[All Fields]) OR (“humans”[MeSH Terms] AND “english”[Language]) AND “adult”[MeSH Terms]) AND 2005/1/1:2021/10/31[Date-Publication])
### Table A1. Cont.

| Search Number | Search Term |
|---------------|-------------|
| SCOPUS        | ((TITLE-ABS-KEY (drown*) OR TITLE-ABS-KEY (submers*)) AND (TITLE-ABS-KEY (death*) OR TITLE-ABS-KEY (mortality*) OR TITLE-ABS-KEY (morbidity*))) AND (TITLE-ABS-KEY ("chronic disease*") OR TITLE-ABS-KEY ("chronic illness*") OR TITLE-ABS-KEY (epilep*) OR TITLE-ABS-KEY (seizure*) OR TITLE-ABS-KEY (arrest*) OR TITLE-ABS-KEY (cardiac) OR TITLE-ABS-KEY (cardio) OR TITLE-ABS-KEY (pulmon*) OR TITLE-ABS-KEY (asystole*) OR TITLE-ABS-KEY (heart*) OR TITLE-ABS-KEY (lung*) OR TITLE-ABS-KEY (diabet*) OR TITLE-ABS-KEY (respir*) OR TITLE-ABS-KEY (neoplasm*) OR TITLE-ABS-KEY (cancer*) OR TITLE-ABS-KEY (musculoskeletal*) OR TITLE-ABS-KEY (digest*) OR TITLE-ABS-KEY (stomatognathic*) OR TITLE-ABS-KEY (lymphat*) OR TITLE-ABS-KEY (vascul*) OR TITLE-ABS-KEY (congenital*) OR TITLE-ABS-KEY (hereditary*) OR TITLE-ABS-KEY (metabol*) OR TITLE-ABS-KEY (endocrin*) OR TITLE-ABS-KEY (immun*) OR TITLE-ABS-KEY (liver*) OR TITLE-ABS-KEY (arrhythmia*) OR TITLE-ABS-KEY ("multiple sclerosis") OR TITLE-ABS-KEY (motor*) OR TITLE-ABS-KEY (dementia*) OR TITLE-ABS-KEY (alzheimer*) OR TITLE-ABS-KEY (parkinson*) OR TITLE-ABS-KEY (nervous*) OR TITLE-ABS-KEY (nerve*) OR TITLE-ABS-KEY (neuro*) OR TITLE-ABS-KEY (amyotrophic lateral sclerosis*) OR TITLE-ABS-KEY (autism*) OR TITLE-ABS-KEY (mental*) OR TITLE-ABS-KEY (psych*) OR TITLE-ABS-KEY ("medical condition*") AND TITLE-ABS-KEY (adult*) AND TITLE-ABS-KEY (human*) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011) OR LIMIT-TO (PUBYEAR, 2010) OR LIMIT-TO (PUBYEAR, 2009) OR LIMIT-TO (PUBYEAR, 2008) OR LIMIT-TO (PUBYEAR, 2007) OR LIMIT-TO (PUBYEAR, 2006) OR LIMIT-TO (PUBYEAR, 2005)) AND (LIMIT-TO (EXACTKEYWORD, "Human") OR LIMIT-TO (EXACTKEYWORD, "Adult") OR LIMIT-TO (EXACTKEYWORD, "Humans") AND (LIMIT-TO (LANGUAGE, "English")) |
| PsycINFO (ProQuest) | (drown* OR submers*) AND (death* OR mortality OR morbidity) AND ((chronic disease*) OR (chronic illness*) OR (epilep*) OR (seizure*) (arrest*) OR (cardiac*) OR (cardio*) OR (pulmon*) OR (asystole*) OR (heart*) OR (lung*) OR (diabet*) OR (respir*) OR (neoplasm*) OR (cancer*) OR (musculoskeletal*) OR (digest*) OR (stomatognathic*) OR (lymphat*) OR (vascul*) OR (congenital*) OR (hereditary*) OR (metabol*) OR (endocrin*) OR (immun*) OR (liver*) OR (arrhythmia*) OR (multiple sclerosis) OR (motor*) OR (dementia*) OR (Alzheimer*) OR (parkinson*) OR (nervous*) OR (nerve*) OR (neuro*) OR (Amyotrophic Lateral Sclerosis*) OR (autism*) OR (addict*) OR (mental*) OR (psych*)) |

Date: After 01 January 2005
Language: English
Age group: Adulthood (18 Yrs & Older)
Population: Human
Table A1. Cont.

| Search Number | Search Term |
|---------------|-------------|
| SPORTSDiscus  | (drown* OR submers* OR river* OR lake* OR shower* OR bath* OR dam* OR beach* OR pool* OR pond* OR ocean) AND (death* OR mortality OR morbidity) AND ((chronic disease*) OR (chronic illness*) OR (epilep*) OR (seizure*) OR (arrest*) OR (cardiac*) OR (cardio*) OR (pulmon*) OR (asystole*) OR (heart*) OR (lung*) OR (diabet*) OR (respir*) OR (neoplasm*) OR (cancer*) OR (musculoskeletal*) OR (digest*) OR (stomatognathic*) OR (lymphat*) OR (vascul*) OR (congenital*) OR (hereditary*) OR (metabol*) OR (endocrin*) OR (immurt*) OR (liver*) OR (arrythmia*) OR (multiple sclerosis) OR (motor*) OR (dementia*) OR (Alzheimer*) OR (parkinson*) OR (nervous*) OR (nerve*) OR (neuro*) OR (Amyotrophic Lateral Sclerosis*) OR (autism*) OR (addict*) OR (mental*) OR (psych*)) |
|               | Limiters—Published Date: 20050101–20211031; Peer Reviewed; Language: English |
|               | Expanders—Apply equivalent subjects |
|               | Search modes—Boolean/Phrase |
| EMBASE (Ovid) | exp Drowning/3 |
| 2             | exp Water Sports/ |
| 3             | exp *Immersion/ |
| 4             | lakes/or exp "oceans and seas"/or ponds/or rivers/or dams/ |
| 5             | bathing beaches/ or swimming pools/ |
| 6             | 1 or 2 or 3 or 4 or 5 |
| 7             | exp Death/ |
| 8             | exp Mortality/ |
| 9             | exp Morbidity/ |
| 10            | 7 or 8 or 9 |
| 11            | exp Chronic Disease/ |
| 12            | exp Epilepsy/ |
| 13            | exp Diabetes Mellitus/ |
| 14            | exp Mental Disorders/ |
### Table A1. Cont.

| Search Number | Search Term                                                                                                                                                                                                                                                                                                                                 |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15            | exp respiratory tract infections/or exp neoplasms/or exp musculoskeletal diseases/or exp digestive system diseases/or exp stomatognathic diseases/or exp respiratory tract diseases/or exp otorhinolaryngologic diseases/or exp nervous system diseases/or exp eye diseases/or exp male urogenital diseases/or exp “female urogenital diseases and pregnancy complications”/or exp cardiovascular diseases/or exp “hemic and lymphatic diseases”/or exp “congenital, hereditary, and neonatal diseases and abnormalities”/or exp “skin and connective tissue diseases”/or exp “nutritional and metabolic diseases”/or exp endocrine system diseases/or exp immune system diseases/or exp “disorders of environmental origin”/or exp occupational diseases/or exp chemically-induced disorders/or exp “wounds and injuries”/ |
| 16            | 11 or 12 or 13 or 14 or 15                                                                                                                                                                                                                                                                                                                   |
| 17            | 6 and 16                                                                                                                                                                                                                                                                                                                                 |
| 18            | 10 and 17                                                                                                                                                                                                                                                                                                                                 |
| 19            | exp adult/                                                                                                                                                                                                                                                                                                                                |
| 20            | 18 and 19                                                                                                                                                                                                                                                                                                                                |
| 21            | limit 20 to (english language and humans and yr = “2005–2021”)                                                                                                                                                                                                                  |

### Appendix B

#### Table A2. Characteristics of Included Studies (n = 83).

| Reference                  | Study Period | Study County | World Bank Region          | Income Level | Evidence Level | Study Population                                                                 | Age Group | Drowning Outcome | Drowning Intent |
|----------------------------|--------------|--------------|-----------------------------|--------------|----------------|----------------------------------------------------------------------------------|-----------|------------------|-----------------|
| Aaltonen et al., 2019 [58] | 1991–2011    | Finland      | Europe and Central Asia     | HIC          | IV             | Suicide after first lifetime psychiatric hospitalisation for depression          | 18+       | X                | X               |
| Ahlm et al., 2015 [59]    | 1992–2009    | Sweden       | Europe and Central Asia     | HIC          | III-3          | Total population drowned in Sweden                                               | 16-85     | X                | X               |
| Bain et al., 2018 [11]    | 2014–2016    | Canada       | North America               | HIC          | III-3          | Epilepsy or seizure with suspicion of drowning                                   | 12-68     | X                | X               |
| Barooni et al., 2007 [30] | 2004         | Canada       | North America               | HIC          | III-3          | Epilepsy population deaths                                                       | 0-90      | X                | X               |
| Bjorkenstam et al., 2016 [60] | 1987–2013    | Sweden       | Europe and Central Asia     | HIC          | IV             | Population with personality disorders                                           | 15-64     | X                | X               |
| Bowman et al., 2010 [31]  | 1999–2005    | USA          | North America               | HIC          | III-3          | Patients with epilepsy                                                          | 0-64      | X                | X               | X               |
| Cenderadewi et al., 2019 [7] | 2006–2014    | Australia    | East Asia and Pacific       | HIC          | III-3          | All age intentional drowning deaths                                              | 0-75+     | X                | X               |
| Reference                          | Study Period | Study County | World Bank Region     | Income Level | Evidence Level | Study Population | Age Group | Drowning Outcome | Drowning Intent |
|-----------------------------------|--------------|--------------|-----------------------|--------------|----------------|------------------|-----------|------------------|----------------|
| Chang et al., 2012 [33]           | 1989–2008    | Taiwan       | East Asia and Pacific | HIC          | III-3          | Deaths with epilepsy | 0-70+     | F                | X               |
| Chang et al., 2014 [32]           | 1981–2010    | USA          | North America         | HIC          | III-3          | Mentions of epilepsy on death certificate | 0-65+     | NF               | X               |
| Cihan et al., 2018 [34]           | 2000–2016    | USA          | North America         | HIC          | III-3          | Epilepsy deaths in water | 20-73     | U                | I               |
| Claesson et al., 2013 [97]        | 2002–2010    | Sweden       | Europe and Central Asia | HIC          | III-3          | Autopsied drowning cases (Swedish National Board of Forensic Medicine) | 22-71     | I                | X               |
| Clemens et al., 2016 [98]         | 2008–2012    | Canada       | North America         | HIC          | III-3          | Drowning incidents in Canada | 15-65+    | F                | X               |
| Ding et al., 2013 [35]            | 2000–2004    | China        | East Asia and Pacific | UMIC         | III-3          | Diagnosis of epilepsy at primary health centre | 10-69     | NF               | U               |
| Fang et al., 2015 [61]            | 2010–2014    | China        | East Asia and Pacific | UMIC         | III-3          | Individuals with psychiatric disorder who committed suicide by drowning | 10-89     | U                | I               |
| Flaig et al., 2013 [62]           | 2006–2010    | Germany      | Europe and Central Asia | HIC          | III-3          | Autopsied non-natural deaths | 18-96     | I                | X               |
| Furumiya et al., 2015 [36]        | 2003–2013    | Japan        | East Asia and Pacific | HIC          | IV             | Elderly persons with dementia who died outdoors after wandering | 70-94     | F                | X               |
| Guay et al., 2019 [63]            | 2005–2014    | Canada       | North America         | HIC          | III-3          | Bathtub drownings in the province of Quebec | 65+       | F                | X               |
| Haines et al., 2010 [64]          | -            | Australia    | East Asia and Pacific | HIC          | III-3          | Completed suicides in Tasmania | -         | NF               | Und            |
| Harris et al., 2010 [64]          | 2006         | USA          | North America         | HIC          | III-3          | Sanctioned triathlete events | -         | U                | I               |
| Harris et al., 2017 [65]          | 1985-2016    | USA          | North America         | HIC          | IV             | Sanctioned triathlete events | 15-80     | U                | X               |
| Hong et al., 2013 [103]           | 2004         | South Korea  | East Asia and Pacific | HIC          | III-3          | Korea National Hospital Discharge Survey | 0-65+     | F                | X               |
| Hossain et al., 2017 [37]         | 2003         | Bangladesh   | South Asia            | LMIC         | III-3          | Adult drowning | 18+        | F                | X               |
| Hunt et al., 2006 [65]            | 1996-2000    | United Kingdom| Europe and Central Asia | HIC          | III-3          | Sample of cases of suicide in England and Wales with recent (c1 year) contact with mental health services | 0-75+     | F                | Und            |
| Jinda et al., 2019 [38]           | 2004–2013    | Thailand     | East Asia and Pacific | UMIC         | III-3          | Seizure-related injuries | 15-80+    | F                | X               |
| Kaiboriboon, et al. 2014 [39]     | 1992-2008    | USA          | North America         | HIC          | III-3          | Hospitalised epilepsy deaths | 18-64     | F                | X               |
| Karlovich et al., 2020 [40]       | 2014–2017    | USA          | North America         | HIC          | IV             | Decedents with a history of seizure or epilepsy | 18-45     | F                | X               |
| Reference                  | Study Period     | Study County         | World Bank Region                        | Income Level | Evidence Level | Study Population                                      | Age Group | Drowning Outcome | Drowning Intent |
|---------------------------|------------------|----------------------|------------------------------------------|--------------|----------------|------------------------------------------------------|-----------|------------------|-----------------|
| Keverkidis et al., 2021   | 2009–2018        | Greece               | Europe and Central Asia                   | HIC          | III-3          | Retrospective case–control study of drowning deaths   | 15-75+    | F                |                 |
| Kielty et al., 2015       | 2006–2016        | Ireland              | Europe and Central Asia                   | HIC          | III-3          | Probable suicide deaths                               | 18-55+    | NF               |                 |
| Kikuchi e al, 2019        | 2015             | Japan                | East Asia and Pacific                     | HIC          | IV             | Dementia patients missing after wandering             | <65-95+   | U                |                 |
| Kim et al., 2021          | 2008–2017        | South Korea          | East Asia and Pacific                     | HIC          | III-3          | Deaths of people with disabilities registered at Ministry of Health and Welfare | 0-80+     | I                |                 |
| Kong et al., 2021         | 2009–2019        | Hunan, China         | East Asia and Pacific                     | UMIC         | III-3          | Accidental deaths during pregnancy and puerperium     | -         | F                |                 |
| Koo et al., 2019          | 2000–2013        | Australia            | East Asia and Pacific                     | HIC          | III-3          | Cases from the Queensland Suicide Register             | 65+       | NF               |                 |
| Kotsiou et al., 2014      | 2012–2013        | Greece               | Europe and Central Asia                   | HIC          | III-3          | Drowning hospitalisations                              | 1888      | U                |                 |
| Kumar et al., 2017        | 2012–2014        | India                | South Asia                               | LMIC         | IV             | Attempted suicides in psychiatric consultation         | 10–50     | I                |                 |
| Lawes et al., 2021        | 2005–2019        | Australia            | East Asia and Pacific                     | HIC          | III-3          | Suicidal deaths along the Australian coast             | 18-70+    | F                |                 |
| Lawes et al., 2021        | 2004–2019        | Australia            | East Asia and Pacific                     | HIC          | III-3          | Males (15–34 years) were compared with other adults (15 years and older) | 15+       | NF               |                 |
| Lee et al., 2019          | 1997–2016        | South Korea          | East Asia and Pacific                     | HIC          | III-3          | Elderly drowning patients                              | 18-65+    | I                |                 |
| Lippmann et al., 2021     | 2007–2016        | New Zealand          | East Asia and Pacific                     | HIC          | III-3          | Diving fatalities                                     | 24-70     | F                |                 |
| Ljusic et al., 2018       | 2001–2010        | Republic of Serbia   | Europe and Central Asia                   | UMIC         | III-3          | Suicide with mental disorders, somatic disorders or without registered disorder | -         | F                |                 |
| Lofman et al., 2011       | 1988–2007        | Finland              | Europe and Central Asia                   | HIC          | III-3          | Suicides in the province of Oulu in Northern Finland | 0-65+     | F                |                 |
| Lunetta et al., 2020      | 1971–2013        | Finland              | Europe and Central Asia                   | HIC          | III-3          | Land motor vehicle drowning                            | 0-99+     | F                |                 |
| Maity et al., 2020        | 2012–2013        | India                | South Asia                               | LMIC         | III-3          | Drowning deaths                                       | 0-70      | F                |                 |
| Markarian et al., 2020    | 2014–2017        | France               | Europe and Central Asia                   | HIC          | III-3          | Adult (>18 years of age) ICU admissions                | 40-74     | F                |                 |
| Reference                  | Study Period | Study County       | World Bank Region       | Income Level | Evidence Level | Study Population                                                                 | Age Group | Drowning Outcome | Drowning Intent |
|----------------------------|--------------|--------------------|-------------------------|--------------|----------------|----------------------------------------------------------------------------------|-----------|-----------------|-----------------|
| Mateen et al., 2012 [44]   | 2005–2008    | Bangladesh         | South Asia              | LMIC         | III-3          | Accidental injury death in people with epilepsy                                  | 12–58     | X               | X               |
| Mbiyvo et al., 2021 [45]   | 2009–2016    | Scotland           | Europe and Central Asia | HIC          | III-3          | Non SUDEP epilepsy related deaths                                                 | ≥16       | X               | X               |
| Meyer-Rochow et al., 2015 [56] | 1982–2011    | Finland            | Europe and Central Asia | HIC          | III-3          | Suicides among visually impaired persons                                            | 20-65+    | X               | X               |
| Mishima et al., 2018 [87]  | 2016         | Japan              | East Asia and Pacific   | HIC          | IV             | Bath-related deaths                                                              | 34–92     | X               | X               |
| Morgan et al., 2008 [88]   | 2001–2005    | Australia          | East Asia and Pacific   | HIC          | III-3          | Surf beach swimmers and surfers                                                    | 13–86     | X               | X               |
| Morris et al., 2016 [46]   | 2002–2011    | South Africa       | Sub-Saharan Africa      | UMIC         | III-3          | Bodies retrieved from water and immersion-related deaths in Pretoria             | 18+       | X               | X               |
| Mu et al., 2011 [47]       | 2005–2009    | China              | East Asia and Pacific   | UMIC         | IV             | Death among people with convulsive epilepsy in rural West China                   | <15–66+   | X               | X               |
| Neves et al., 2020 [48]    | -            | Portugal & UK      | Europe and Central Asia | HIC          | IV             | Patients with Parkinson’s Disease Mean = 64                                      | X         | X               | X               |
| Nishida et al., 2015 [73]  | 2006–2013    | Japan              | East Asia and Pacific   | HIC          | IV             | Patients diagnosed with early post stroke depression who died                    | 65–94     | X               | X               |
| Okuda et al., 2015 [49]    | 2003–2013    | USA                | North America           | HIC          | IV             | Deaths in bathtubs                                                               | 22–96     | X               | X               |
| Pan et al., 2021 [74]      | 2001–2016    | Taiwan             | East Asia and Pacific   | HIC          | III-3          | Suicide mortality in patients with schizophrenia                                 | <20–≥80+  | X               | X               |
| Papadodima et al., 2007 [89]| 1997–2004    | Greece             | Europe and Central Asia | HIC          | III-3          | Drowning deaths                                                                  | <15–74+   | X               | X               |
| Park et al., 2013 [75]     | 1995–2006    | South Korea        | East Asia and Pacific   | HIC          | III-3          | Psychiatric patients who suicide                                                  | 10–70+    | X               | X               |
| Peden et al., 2019 [108]   | 2005–2014    | Australia/Canada/ NZ| HIC                      | III-3        |                 | Residents                                                                       | 0–65+     | X               | X               |
| Peden et al., 2016 [57]    | 2002–2012    | Australia          | East Asia and Pacific   | HIC          | III-3          | River drowning                                                                   | 0–75+     | X               | X               |
| Peden et al., 2016 [107]   | 2002–2012    | Australia          | East Asia and Pacific   | HIC          | III-3          | International tourists to Australia                                              | 0–55+     | X               | X               |
| Peden et al., 2019 [19]    | 2002–2012    | Australia          | East Asia and Pacific   | HIC          | III-3          | Bathtub drowning                                                                 | 65–85+    | X               | X               |
| Purandare et al., 2009 [50] | 1996–2004    | United Kingdom     | Europe and Central Asia | HIC          | III-3          | Suicide among those with dementia                                                 | 65+       | X               | X               |
Table A2. Cont.

| Reference                  | Study Period | Study County | World Bank Region | Income Level | Evidence Level | Study Population | Age Group | Drowning Outcome | Drowning Intent |
|-----------------------------|--------------|--------------|-------------------|--------------|----------------|------------------|-----------|------------------|-----------------|
| Reizine et al., 2021 [76]   | 2013–2020    | France       | Europe and Central Asia | HIC         | IV             | Drowning in fresh and sea water | Mean 68    | X                | X               |
| Rowe et al., 2011 [51]      | 2003–2008    | USA          | North America     | HIC         | IV             | Persons with dementia who go missing | 40–95     | X                |                 |
| Runeson et al., 2010 [77]   | 1973–1982    | Sweden       | Europe and Central Asia | HIC         | III-3          | Completed suicides among those treated for attempted suicide | 10+       | X                |                 |
| Satoh et al., 2013 [20]     | 1998–2007    | Japan        | East Asia and Pacific | HIC         | III-3          | Sudden deaths in hot bathtubs | 6–95      | X                | X               |
| Schaffer et al., 2014 [78]  | 1998–2010    | Canada       | North America     | HIC         | III-3          | Suicide in bipolar disorder | <24–65+   | X                |                 |
| Schnepp et al., 2021 [90]   | 1997–2017    | Germany      | Europe and Central Asia | HIC         | IV             | Deaths in water | 1–90      | X                | X               |
| Selvaraj et al., 2020 [79]  | 2017–2018    | India        | South Asia        | LMIC        | IV             | Drowning in Madurai Region | 0–70+     | X                | X               |
| Sillanpaa et al., 2010 [52] | 1964–2002    | Finland      | Europe and Central Asia | HIC         | IV             | Long-term mortality among those with childhood-onset epilepsy | 1–50      | X                |                 |
| Stemberg et al., 2010 [80]  | 1981–2005    | Croatia      | Europe and Central Asia | HIC         | III-3          | Suicidal drowning deaths | 23–86     | X                | X               |
| Stephenson et al., 2020 [81] | 1988–2017   | Australia    | East Asia and Pacific | HIC         | IV             | Urban section of the River Torrens | 18–76     | X                | X               |
| Suzuki et al., 2015 [53]    | 2009–2011    | Japan        | East Asia and Pacific | HIC         | III-3          | Autopsied bath-related deaths | 0–90+     | X                |                 |
| Tellier et al., 2019 [54]   | 2011–2016    | France       | Europe and Central Asia | HIC         | III-3          | Gironde surf beaches | 0–65+     | X                |                 |
| Tester et al., 2011 [91]    | 1998–2010    | USA          | North America     | HIC         | IV             | Unexplained drowning victims referred for a cardiac channel molecular autopsy | 3.5–69    | X                |                 |
| Tikka et al., 2021 [92]     | 1975–2015    | Finland      | Europe and Central Asia | HIC         | IV             | Land motor traffic crash related drownings | Mean 34.7 | X                | X               |
| Tzimas et al., 2016 [93]    | 2003–2011    | Germany      | Europe and Central Asia | HIC         | IV             | Water-related deaths with adequate genetic material for DNA analysis | 20–50     | X                | X               |
| Vinkel et al., 2016 [94]    | 1999–2012    | Denmark      | Europe and Central Asia | HIC         | III-3          | Diving-related fatalities | 21–59     | X                |                 |
| Walker et al., 2006 [95]    | 2001         | Australia    | East Asia and Pacific | HIC         | III-3          | Diving-related fatalities | 21–81     | X                | X               |
| Walker et al., 2009 [96]    | 2004         | Australia    | East Asia and Pacific | HIC         | III-3          | Diving-related fatalities | 20–65     | X                |                 |
| Williams et al., 2018 [82]  | 2013–2017    | USA          | North America     | HIC         | III-3          | Actively serving US armed forces | <20–40+ years | X                | X               |
Table A2. Cont.

| Reference          | Study Period | Study County | World Bank Region         | Income Level | Evidence Level | Study Population                                      | Age Group | Drowning Outcome | Drowning Intent |
|--------------------|--------------|--------------|----------------------------|--------------|----------------|-------------------------------------------------------|-----------|------------------|-----------------|
| Wingren et al., 2016 [101] | 1999–2013    | Sweden       | Europe and Central Asia    | HIC          | III-3          | Suicide where body mass index was known                | 18–70+    | X                | X               |
| Yang et al., 2018 [55]     | 2008–2015    | South Korea  | East Asia and Pacific      | HIC          | III-3          | Bath-related deaths                                   | 18–91     | X                | X               |
| Youn et al., 2009 [56]     | 1998–2007    | South Korea  | East Asia and Pacific      | HIC          | III-3          | OHCA due to drowning patents admitted to St Mary’s Hospital | 3–87      | X                | X               |

Abbreviations: HIC—high income country; LMIC—lower middle income country; LIC—low income country; OHCA—Out of Hospital Cardiac Arrest; UMIIC—upper middle income country; SUDEP—Sudden Unexpected Death in Epilepsy; UK—United Kingdom; Study evidence level: III-3 (comparative studies with concurrent controls and allocation not randomised (cohort studies), case control studies, or interrupted time series with a control group; Level IV (case studies with either post-test or pre-test/post-test outcomes).
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