



OPEN ACCESS

Fatal river drowning: the identification of research gaps through a systematic literature review

Amy E Peden,^{1,2} Richard C Franklin,^{1,2} Peter A Leggat^{2,3}

► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/injuryprev-2015-041750>).

¹Royal Life Saving Society—Australia, Broadway, New South Wales, Australia

²College of Public Health, Medical and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia

³Research School of Population Health, College of Medicine, Biology and Environment, Australian National University, Canberra, Australian Capital Territory, Australia

Correspondence to

Amy E Peden, Royal Life Saving Society – Australia, PO Box 558, Broadway, NSW 2007, Australia; apeden@rissa.org.au

Received 5 July 2015

Revised 17 November 2015

Accepted 28 November 2015

Published Online First

4 January 2016

ABSTRACT

Introduction Drowning is a leading cause of unintentional death. Rivers are a common location for drowning. Unlike other location-specific prevention efforts (home swimming pools and beaches), little is known about prevention targeting river drowning deaths.

Methods A systematic literature review was undertaken using English language papers published between 1980 and 2014, exploring gaps in the literature, with a focus on epidemiology, risk factors and prevention strategies for river drowning.

Results Twenty-nine papers were deemed relevant to the study design including 21 (72.4%) on epidemiology, 18 (62.1%) on risk factors and 10 (34.5%) that proposed strategies for prevention. Risk factors identified included age, falls into water, swimming, using watercraft, sex and alcohol.

Discussion Gaps were identified in the published literature. These included a lack of an agreed definition for rivers, rates for fatal river drowning (however, crude rates were calculated for 12 papers, ranging from 0.20 to 1.89 per 100 000 people per annum), and consensus around risk factors, especially age. There was only one paper that explored a prevention programme; the remaining nine outlined proposed prevention activities. There is a need for studies into exposure patterns for rivers and an agreed definition (with consistent coding).

Conclusions This systematic review has identified that river drowning deaths are an issue in many regions and countries around the world. Further work to address gaps in the published research to date would benefit prevention efforts.

INTRODUCTION

Drowning is a global public health issue, with the WHO estimating 372 000 people die from drowning annually.¹ The true burden of drowning is likely to be higher due to under-reporting, as victims are not hospitalised or cases are not recorded because of a lack of death collection tools in many low- and middle-income countries (LMICs).² Some data on drowning are also excluded because of reporting methods such as the use of International Classification of Diseases (ICD) coding frameworks that mean drowning may be classified elsewhere or excluded if it is related to transportation or disaster.¹

Drowning prevention interventions based on site-specific locations are likely to have a greater impact and prove more successful than general strategies aimed at preventing drowning.³ A significant reduction in the number of drowning deaths among young children in private swimming pools has been achieved through over 30 years of focused work on

the epidemiology and risk factors for drowning in private swimming pools among young children.^{4–8} A focus on beaches has also seen prevention efforts in that space be successful.^{9–11} Strategies which target specific aquatic locations may also prove to be successful, as they allow ownership of the issue. In Australia for example, local councils are responsible for beaches and publicly owned swimming pools, and individuals are responsible for private swimming pools.

The ICD10¹² currently divides aquatic locations into the subsets of ‘bathtub’, ‘swimming pool’ and ‘natural waterway’. The category of ‘natural waterway’ is broad and includes rivers, creeks, beaches, oceans, harbours, lakes and dams, thus not providing the fidelity to extract rivers. In 2004, the International Classification of External Causes of Injury (ICECI) Coordination and Maintenance Group articulated a classification for ‘body of water’ that allows the identification of river, stream (15.02.25).¹³ This information is needed to undertake site-specific research and develop targeted interventions.

To date, there has been limited research that has explored drowning in locations other than beaches and swimming pools. Inland waterways such as rivers, creeks, streams, lakes and dams regularly account for large proportions of drowning deaths,^{14–16} particularly in LMICs. In LMICs, drowning often occurs as a result of the activities associated with daily life¹⁷ rather than the recreational undertakings often being conducted before drowning in high-income countries (HICs).^{18–20}

In Australia, rivers routinely claimed the largest number of lives in annual national drowning reports between 2011 and 2014,^{21–24} and rivers accounted for 20.3% of unintentional fatal drowning in the 5 years between 2002 and 2007.⁴ Inland waterways (rivers, creeks, streams, lakes, dams and lagoons) have been deemed a key priority location by the Australian Water Safety Council (AWSC) where sustained action is required to achieve the aim of a 50% reduction in national drowning deaths by the year 2020.^{25 26}

Proposed contributory factors for drowning in rivers include a lack of barriers controlling access to water, an absence of adult supervision for young children, poor swimming skills, minimal awareness of the dangers, the consumption of alcohol, transportation on water, a lack of safe water supply, and disasters related to flooding.¹ Some proposed river prevention strategies include: community-based prevention; provision of safe places such as crèches for young children; basic swimming instruction for older children; increased public awareness of the vulnerability of children; legislation for safe



Open Access
Scan to access more
free content



CrossMark

To cite: Peden AE, Franklin RC, Leggat PA. *Inj Prev* 2016;**22**:202–209.

boating; mitigation of flood risk; and continued research into priority areas.¹

AIMS

There is a need for a better understanding of the burden of river drowning as well as related risk factors to assist in the development of targeted and evidence-based strategies for prevention. This systematic review of peer-reviewed literature for fatal unintentional river drowning aims to:

- ▶ describe the epidemiology of fatal river drowning;
- ▶ describe risk factors for drowning in rivers;
- ▶ identify and critically analyse strategies for prevention; and
- ▶ identify gaps in research to date and propose priority areas where further work is required.

METHODS

This systematic literature review explored literature published in the English language between 1980 and 2014 using the databases Medline, Scopus, ScienceDirect, PsychInfo, SportDiscuss, the Cochrane Central Register for Controlled Trials, and SafetyLit.

For this study, the internationally accepted definition of drowning has been used;²⁷ however, as this study explored papers over a 35-year period, not all papers used this definition. Any papers which used the words ‘river’, ‘creek’ or ‘stream’ (ie, those papers that said they were exploring unintentional fatal drowning in these locations) were included.

Initial search terms used were ‘drown*’ limited to English language, human and a published date range between 1 January 1980 and 31 December 2014. Searches were then refined to include ‘drown*’ and ‘river*’ or ‘creek*’ or ‘stream*’ or ‘fresh water’ limited to peer-reviewed publications (see online supplementary table S1a).

Two reviewers assessed the papers against the inclusion/exclusion criteria. Titles and abstracts were screened for these criteria by two reviewers (AEP, RCF). Where there was not consensus, there was the possibility of a third reviewer (PAL); however, this was not required. Review papers (ie, papers that did not present primary data; $n=1$)²⁸ were excluded from this study. A hand-search technique was used to identify any additional primary data sources in the paper’s references. A manual search was completed for all references retained for data extraction excluding grey literature.

Papers were assessed according to the following inclusion/exclusion criteria: (1) the drowning event was unintentional; (2) the literature included reference to rivers and/or creeks and/or streams. Exclusions included: intentional drowning (suicide) or homicide as a result of drowning; the forensic investigation of drowning (eg, autopsies and how to identify drowning in cases of fresh water drowning). Conference abstracts, even if published in the peer-reviewed literature, were excluded.

Papers where the main focus was flood-related drowning were excluded, as flooding differs from the normal river process with different risks and should therefore be dealt with separately to river drowning deaths during non-flooding periods.^{29 30}

Risk factors were defined as an attribute (such as personal behaviour or lifestyle), environment (such as speed of water flow, depth of water, objects in the water) or an inborn or inherited characteristic (such as age, sex) that on the basis of evidence is known to increase the probability of a specified outcome, be it injury, death or disease.³¹ Preventive stratagems were defined as any activity aimed at reducing river drowning.

With respect to rivers (ie, rivers, creeks and streams), the following definitions from the Australian context were used. River

was defined as ‘...a natural waterway that may be fed from other rivers or bodies of water draining water away from a ‘catchment area’ to another location...’.³² ‘Rivers can vary in water flow, length, width and depth’.³³ A creek was defined as ‘a water body that may be fed by rivers and other creeks. A creek is generally smaller in size than a river and is often characterised by intermittent water flow. Creeks can be prone to more extreme conditions of stasis in drought and flash flooding after rainfall’.³³ A stream was defined as ‘a body of flowing water generally smaller than a river. May also be seasonal but may not always contain water’.³³

To reduce the size of tables 1 and 2 and to present the information consistently, categories (data sources and risk factors) have been given a numeric value—for example, death certificate is coded as 1 in table 1. These can be found at the bottom of tables 1 and 2. Coding was used for the different hazards presented by rivers—for example, currents and drop offs were coded together as ‘river characteristics’ in table 2 and given the numeric code ‘10’.

Where data on populations of the country or region being analysed, as well as the number of river drowning deaths, were made available, a crude rate of river drowning per 100 000 population was calculated. Where a drowning rate was presented as well as the proportion of all drowning deaths that rivers accounted for as a percentage, this proportion was used on the overall drowning rate to calculate a crude river drowning rate per 100 000 population.

The methodological quality of the papers that proposed strategies for prevention included in the review were assessed using the National Health and Medical Research Council (NHMRC) Levels of Evidence.⁵⁵

RESULTS

A large number of papers were excluded because of a lack of specificity around unintentional fatal drowning specific to rivers. Several papers were included because they mentioned rivers as a category of location and their burden within the overall number of drowning deaths, but any further analysis, including identifying risk factors, could not be extracted from the broader grouping of ‘freshwater’.^{34 44 47}

Others were excluded because they did not focus on unintentional drowning. Papers where unintentional drowning in rivers could not be separated from fatal river drowning as a result of suicide and/or homicide were also excluded.^{56–61}

Papers were excluded from the systematic review if they focused on both fatal and non-fatal drowning, such as hospital admissions due to drowning, without making distinction between the two by location,^{62 63} as the present study expressly focused on fatal river drowning.

Initial search results returned 895 papers, and all papers were extracted into EndNote (see online supplementary figure S1)⁶⁴ Duplicate papers ($n=224$) were removed leaving 671 references. After a title search, 417 papers were removed. Abstracts were reviewed for 254 papers, and 116 papers were removed. The full text for 138 papers was assessed against the inclusion and exclusion criteria, and a further 114 papers were removed. Hand searches of the initial 24 papers included in the review were undertaken and identified a further five papers, resulting in 29 papers for review (see online supplementary table S1b). Of the 29 papers found, 21 (72.4%) included epidemiological information, 18 (62.1%) included information on risk factors for drowning in rivers, and 10 (34.5%) were identified as proposing prevention strategies.

Table 1 Relevant papers identifying prevalence of fatal drowning in rivers (n=21)

Reference	Country/area of country	Study country income level	Year(s)	Population	Data source/ ICD8, 9, 10, none, unknown	Terminology	Population based (Y/N)	Number of river drowning deaths	% of river drowning deaths	Rate/100 000 population	Activity prior to drowning
Brenner <i>et al</i> ³⁴	USA	HIC	1995	Children aged <20 years	1 (ICD9)	River, creek	Y	235	17	UTBC	Not discussed
Byard and Lipsett ³⁵	Australia (South Australia)	HIC	March 1963 to February 1998	Children <2 years of age	3 (None)	River	N—Case Series	3	9	UTBC	Not discussed
Cass <i>et al</i> ³⁶	Australia (New South Wales)	HIC	1987–1990	Children less than 15 years	5 (None)	Rivers and creeks	N; case series	10	16	UTBC	70% wading near shore (caught by current or lost footing)
Cass <i>et al</i> ³⁷	Australia (New South Wales)	HIC	1990–1995	Children aged 0–14 years	2 (None)	Rivers	Y	5	4	UTBC	100% playing or swimming in the water
Davis <i>et al</i> ³⁰	USA (New Mexico)	HIC	1975–1980	People aged 0–24 years	1 (None)	Rivers	Y	63	19	0.82*	'Most victims involved in activities near but not in the water'
Dietz and Baker ³⁸	USA (Maryland)	HIC	1972	All accidental drowning deaths	6 (None)	Rivers or creeks	Y	61	52	1.56*	37.7% Boating 31.1% Swimming 24.6% Fell or stepped into deep water
Fang <i>et al</i> ³⁹	China (Xiamen city and suburbs)	LMIC	2001–2005	Children aged 1–4 years	1 (ICD9, 10)	River	Y	7	10	0.38*	Not discussed
Fife <i>et al</i> ⁴⁰	USA (New Jersey)	HIC	1981–1985	All immersion injuries leading to hospital admission or death	1 (ICD9)	River	Y	66	16	0.21*	Not discussed
Franklin <i>et al</i> ⁴¹	Australia	HIC	1989–1992	Unintentional fatalities occurring in the farm environment	2, 8 (Unknown)	Rivers and creeks	Y	15	22	UTBC	Not discussed
Franklin <i>et al</i> ⁴	Australia	HIC	1 Jul 2002 to 30 Jun 2007	All unintentional fatal drowning in Australia	2, 8 (None)	Rivers	Y	295	20	0.29*	20.7% Fall 20.3% Unknown 18.6% Other
Iqbal <i>et al</i> ⁴²	Bangladesh (Matlab)	LMIC	1985–2000	Children aged 1–4 years	7 (None)	Rivers	Y	44	4.4	UTBC	Not discussed
Kiakalayeh <i>et al</i> ⁴³	Iran (Guilan and Mazandran)	LMIC	20 Mar 2005 to 20 Mar 2006	Resident (R) and tourists (T)	7, 1, 4 (ICD10)	River	Y	85 (75 R 10 T)	25% (88.2% R 11.8% T)	1.89†	Not discussed
Lunetta <i>et al</i> ⁴⁴	Finland	HIC	1998–2000	All ages	8 (ICD8, 9, 10)	River	Y	92	13.1	0.58*	Not discussed
Newman <i>et al</i> ⁴⁵	USA (five counties of Washington State)	HIC	1987 to 1996	Individuals > 12 months to 19 years who died of injuries sustained while involved in recreational wilderness activity	6 (None)	River	N; case series	15	37.5	UTBC	46.7% Swimming 33.3% Falls 20.0% Watercraft
Nixon <i>et al</i> ⁵	Australia (Brisbane (Queensland))	HIC	1967–1981	Childhood (0–15 years)	99 (None)	Creeks, rivers	Y	20	15.0	0.53*	Not discussed
O'Hare <i>et al</i> ⁴⁶	New Zealand	HIC	1983–1995	Deaths as a result of recreational river rafting	8 (ICD9)	Rivers	N; case series	31	93.9	UTBC	100% Watercraft
Patteta and Biddinger ⁴⁷	USA (North Carolina)	HIC	1980–1984	All people	1 (None)	River or creek	Y	309	29.4	0.94*	Not discussed
Rahman <i>et al</i> ¹⁵	Bangladesh (rural and urban communities)	LMIC	2003	Children 0–17	4 (None)	River	Y	96	5.2	1.42*	Not discussed

Continued

Table 1 Continued

Reference	Country/area of country	Study country income level	Year(s)	Population	Data source/ ICD8, 9, 10, none, unknown	Terminology	Population based (Y/N)	Number of river drowning deaths	% of river drowning deaths	Rate/100 000 population	Activity prior to drowning
Riley <i>et al</i> ⁴⁸	Australia (Tasmania)	HIC	1981–1993	Children <15	2 (None)	Rivers	Y	7	20.6	1.01*	Not discussed
Tan ⁴⁹	Singapore	HIC	1992–2001	All ages	1 (None)	Rivers	Y	74	15.1	0.20†	Not discussed
Wentworth <i>et al</i> ⁵⁰	Canada (Brant County)	HIC	1969–1992	All ages	3 (None)	River, creek	Y	16	33.3	UTBC	37.5% Falls 18.8% Watercraft 18.8% Swimming

Data source: 1, death certificates; 2, coronial records; 3, autopsy reports; 4, household surveys; 5, hospital medical records; 6, medical records (eg, records at the office of the chief medical examiner); 7, surveillance system; 8, country level statistics organisations (eg, Statistics Finland, Australian Bureau of Statistics (ABS) and New Zealand Health Information System); 9, unknown.

*Rate calculated using overall drowning rate and proportion of river drowning within overall drowning.

†Rate calculated using available population and drowning data in respective paper.

HIC, high-income country; ICD, International Classification of Disease; LMIC, low- and middle-income country; UTBC, unable to be calculated.

Table 2 Relevant papers discussing risk factors for fatal drowning in rivers (n=18)

Reference	Country/area of country	Risk factors	Type of study
Ahmed <i>et al</i> ⁵¹	Bangladesh (Matlab)	1, 2	Population based
Byard and Lipsett ³⁵	Australia (South Australia)	4	Case series
Cass <i>et al</i> ³⁶	Australia (New South Wales)	8, 10, 18	Case series
Cass <i>et al</i> ³⁷	Australia (New South Wales)	2, 9, 4	Case series
Davis <i>et al</i> ³⁰	USA (New Mexico)	6, 12	Population based
Fang <i>et al</i> ³⁹	China (Xiamen city and suburbs)	11	Population based
Franklin <i>et al</i> ⁴	Australia	12, 6, 7, 99	Population based
Howland <i>et al</i> ⁶²	USA (Massachusetts)	3	Telephone survey
Kauffman ⁵³	USA (Potomac River–West Virginia, Maryland, Virginia, Washington DC)	10, 3, 13, 18	Case studies
Kiakalayeh <i>et al</i> ⁴³	Iran (Guilan and Mazandran)	17, 12	Population based
Lunetta <i>et al</i> ⁴⁴	Finland	3	Population based
Newman <i>et al</i> ⁴⁵	USA (five counties of Washington State)	4, 12, 1, 5, 7, 14	Case series
Nixon <i>et al</i> ⁵	Australia (Brisbane (Queensland))	16	Unknown
O'Hare <i>et al</i> ⁴⁶	New Zealand	14, 17	Case series
Patetta and Biddinger ⁴⁷	USA (North Carolina)	3	Population based
Riley <i>et al</i> ⁴⁸	Australia (Tasmania)	12	Case series
Sorey <i>et al</i> ⁵⁴	USA	15	Case series
Wentworth <i>et al</i> ⁵⁰	Canada (Brant County)	4, 12, 3, 6, 7	Population based

Risk factor coding: 1, summer months; 2, exposure; 3, alcohol; 4, being male; 5, daylight hours; 6, falls into water; 7, swimming; 8, rurality; 9, risk-taking behaviour; 10, river characteristics (eg, caught in current, lost footing due to steep/sharp drop offs); 11, lack of swimming ability; 12, age; 13, not wearing lifejackets; 14, using watercraft; 15, river tree rope swings; 16, lower survival rates/more likely to experience a bad outcome; 17, resident of the area they drowned in (as opposed to a tourist); 18, lack of river knowledge; 19, monsoon period; 20, absence of supervision; 99, unknown activity.

Epidemiology

Of the 21 papers, seven (33.3%) examined drowning data at a national level, and 14 at a sub-national level. The time periods ranged from a single year^{15 34 38 43} to 35 years.³⁵ Nine studies (42.9%) focused on all ages, and 10 (47.6%) focused on children. Two papers focused on specific populations (farm environment⁴¹ and recreational river rafting⁴⁶). Eight papers (38.1%) included information on activity prior to drowning. Falls were the most common activity, followed by swimming and watercraft (table 1).

The three most common data sources used were death certificates (33.3%), country level statistics organisations (19.0%) and autopsy reports (9.5%). Three papers used multiple data sources, two used a combination of coronial records and country level statistics organisations,^{4 41} and the other a combination of a surveillance system, death certificates and household surveys⁴³ (table 1).

The burden of drowning in rivers ranged from 3.8% of all drowning deaths among children 0–14 years in the Australian state of New South Wales³⁷ to 52.0% in the USA state of Maryland in 1972.³⁸ The crude rate of river drowning per

100 000 population varied from 0.38³⁹ to 1.89⁴³ in LMICs and from 0.20⁴⁹ to 1.56³⁸ in HICs (table 1).

Risk factors

Risk factors identified included: age (33.3%); activity prior to drowning (33.3%), of which falls into water (16.7%), swimming (16.7%) and using watercraft (11.1%) were identified; being male (22.2%); alcohol (27.8%). Where age was a risk factor, the age groups identified were children (5–14 years),⁴⁸ adolescents,³⁰ teenagers (12–18 years),⁴⁵ young people (under 39 years),⁵⁰ adults (18–49 years)⁴ and older people (70+ years).⁴³ Common groupings of risk factors included age and falls^{4 30 50} and age, being male and swimming^{45 50} (table 2).

Strategies for prevention

There were nine papers proposing prevention strategies (table 3), and only one paper that explored the effectiveness of a river drowning prevention strategy. This paper observed the use of lifejackets by children at three popular local river beaches in Sacramento County, California.⁶⁵ Of the nine papers which proposed prevention strategies, education was mentioned in six (66.7%). Other proposed strategies included fencing,^{43 37 67} signage,⁵³ depth gauges,⁵³ grills,⁴³ covers,⁶⁷ lifejackets,^{34 45 53 54 65} legislation and enforcement,⁶⁵ and supervision.^{45 62}

Proposed education-based prevention strategies included targeting education at older boys who were deemed more likely to be risk takers³⁷ and young men on the risks of jumping from a height into water.⁶⁶ Education on river conditions (depth of the

river, velocity and deceptiveness) through the use of public service announcements was suggested.⁵³ Encouraging river users to recognise water conditions such as currents and the impact on personal swimming ability⁴⁵ was also recommended, as well as education for users of river tree rope swings about the potential risk of injury and for land managers about associated liabilities.⁵⁴ Evidence for papers citing proposed strategies for prevention was generally low, classified as level IV in 90.0% of papers, with only one paper being classified as level III-3.⁶⁵

DISCUSSION

There is currently no clear consistent definition of 'river', making this review challenging. Consideration was given to the types of terms used to classify rivers as well as whether any papers attempted to define river, creek and stream locations. No papers included in this systematic review included information as to how rivers were defined. As such, in this paper it is the first time that a definition of the aquatic location of 'river' has been provided.

The exploration of river drowning is also challenging given the use of ICD coding that does not allow the isolation of studies associated with rivers.¹² Being unable to quantify the burden of drowning in rivers makes the identification of river-specific risk factors difficult. This impedes the development of location-based strategies for prevention. For example, in Australia, 64.3% of drowning deaths would occur in the ICD10-coded natural waterways of beach, ocean, lake and river.²⁴

Table 3 Relevant papers discussing proposed prevention strategies for fatal river drowning (n=10)

Reference	Country/area of country	Prevention strategies	Level of evidence
Wintemute <i>et al</i> ⁶⁵	USA (observation sessions at 3 popular local river beaches in Sacramento County, California)	Lifejackets made available for use without charge by swimmers at popular local river beaches. Statutory requirements: ordinances making it unlawful for parents or guardians to allow children under 13 to enter rivers without lifejackets Enforcement: higher lifejacket use is likely if enforced	III-3 Observational study and expert opinion
Reference	Country	Proposed prevention strategies	Level of evidence
Brenner <i>et al</i> ³⁴	USA	Lifejackets (when boating or playing near rivers)	IV Population-based study
Cass <i>et al</i> ³⁷	Australia (New South Wales)	Education (targeted at older boys who are prone to risk-taking behaviour) Engineering: fencing house to separate from hazard)	IV Expert opinion and case series
Kauffman ⁵³	USA (Potomac River–West Virginia, Maryland, Virginia, Washington DC)	Education: public service announcements of river conditions Engineering: river depth gauges with interpretive signs Administrative: signage on risks of river Lifejackets as a prevention strategy	IV Expert opinion and case series
Kemp and Sibert ⁶²	UK	Supervision Engineering: restrict access for swimming Education: youth organisations not to organise swimming parties in rivers	IV Expert opinion and case series
Kiakalayeh <i>et al</i> ⁴³	Iran (Guilan and Mazandran)	Engineering: fences and grills	IV Expert opinion
Moran ⁶⁶	Australia and New Zealand	Education: young men about safe behaviours and inherent risks of jumping from a height into water	IV Expert opinion
Nakahara <i>et al</i> ⁶⁷	Japan	Engineering: fences or covers for rivers	IV Population-based study
Newman <i>et al</i> ⁴⁵	USA (five counties of Washington State)	Education: recognition of water conditions such as currents and personal swimming ability Basic water safety instruction for children Supervision and lifejacket use should be emphasised when children are around water	IV Case series
Sorey <i>et al</i> ⁵⁴	USA	Education: awareness of injuries or liabilities Lifejackets, especially for non-swimmers	IV Expert opinion and case series

Epidemiology

While rivers were found to be the leading location for drowning in several papers,^{4 56 68} the majority of papers focused on the burden of drowning generally—of which river drowning may be a component—rather than national population-level epidemiological studies on the prevalence of river drowning. No papers provided a rate for drowning deaths in rivers; however, 12 papers provided sufficient information to calculate a crude fatal drowning rate, which ranged from 0.20⁴⁹ to 1.89⁴³ per 100 000 population.

Future studies of fatal drowning should provide rates based on location to allow comparison between papers. It should be noted that population-based rates do not take exposure into account. Future studies should also aim to identify exposure at river locations to calculate more accurate drowning rates.

Age groups found to be at risk ranged from children (5–14 years)⁴⁸ to older people (70+ years).⁴³ Further work needs to be undertaken to determine which age groups are at risk and why there is such variance. We postulate that this variance is due to exposure.

Exploration of common activities prior to drowning was rare, with only seven papers including information of this type. Activities included falls into water,^{4 30 50 69} swimming,^{4 45 50} using watercraft^{46 45} and river tree rope swings.⁵⁴ Two papers also identified unique considerations for the prevention of fatal river drowning, namely the farm environment⁴¹ and those who drown as a result of recreational river rafting.⁴⁶ These papers identify the need for epidemiological studies to isolate the different causal factors for fatal river drowning in order to identify applicable prevention strategies.

Risk factors

Rivers have been identified as being a particularly risky location, with drownings more likely to result in a fatal outcome.⁵ Being male was highlighted as a risk factor,^{35 37 45 50} as was age (although consensus was lacking).^{4 30 38 48 45 50} Teenagers and young adults, most commonly male, and their propensity towards risk-taking behaviour were identified in several papers.^{30 45 66}

Other risk factors included: a lack of swimming ability;³⁹ underestimating the risk that river conditions can pose;⁵³ local residents (rather than tourists);^{43 46} rurality of river location;^{48 36 51} use of tree rope swings;⁵⁴ and reluctance to use lifejackets.⁵³ Children who play in and around rivers without adult supervision were also recognised as being at increased risk of drowning,⁷⁰ although adult supervision may still not be effective in preventing river drowning deaths in children in some circumstances.⁴⁵

Alcohol was acknowledged as a risk factor for drowning in rivers in a number of papers,^{44 47 50 52 53 69} with one paper finding 74.0% of all river drowning deaths to be alcohol-related.⁴⁴

Much of the evidence to support the proposed risk factors for river drowning is based on population-based studies or case series. Several risk factors identified for river drowning are known risk factors for drowning, such as being male, the consumption of alcohol, and exposure to the hazard. Evaluations of proposed prevention strategies are needed to determine if strategies addressing general drowning risk factors are successful in the specific context of river drowning prevention. Other risk factors for river drowning identified in this systematic review may warrant further testing, such as lack of swimming ability, lack of knowledge of rivers as a hazard, and river characteristics.

Exposure studies will also assist in identifying if a lack of consensus based on age as a risk factor is due to the variety of activities being undertaken prior to drowning in rivers. We postulate that rivers are multipurpose settings, which poses a challenge for prevention.

Strategies for prevention

There was only one study that discussed the evaluation of a prevention strategy for fatal river drowning through the use of lifejackets; however, the strategy was found to increase lifejacket use rather than prevent drowning.⁶⁵ Five papers made reference to strategies proposed in the WHO Global Report on Drowning,¹ most commonly restricting access to water through barriers,^{43 37 62 67} and basic swimming instruction for children;⁴⁵ however, none had been evaluated. Engineering solutions to restrict access such as grills⁴³ and covers⁶⁷ were not well explained in the literature and are unlikely to be successful in open water environments such as rivers. There were nine other papers which discussed possible strategies and these were grouped around education, restricting access, lifejackets, signage, depth gauges, swimming skills and adult supervision of children.^{34 37 43 45 53 54 62 67 66}

While supervision was commonly mentioned as a prevention strategy, one study stated that none of the victims were on their own when they drowned, teenagers usually were with peers and younger children with adults.⁴⁵ This has important implications for drowning prevention in rivers, as the presence of a ‘supervisor’ may not necessarily ensure supervision. Supervision as a prevention strategy should be clearly explained to include elements of responsibility (adult, sober), proximity, attention, continuity^{8 71 72} and preparedness.⁸ There would be benefit in a consistently applied universal definition for supervision.⁸

There are a range of contributory factors that lead to drowning in rivers. Any interventions designed to be successful in preventing drowning in such aquatic locations must be evidence based and take into account factors such as exposure.⁷³ Further research is required to determine if strategies that are in place at other aquatic locations, such as lifeguard patrols at beaches, would be successful at river locations.

Ninety per cent of papers proposing strategies for the prevention of river drowning were classified as level IV, which represents a low level of quality. Well-designed and executed studies evaluating proposed strategies for prevention of river drowning are needed.

Additional research gaps

National population-based studies that specifically focus on the prevalence of river drowning among all age groups are urgently required. These studies should focus on the burden of river drowning as well as quantifying proposed risk factors such as age, sex, alcohol and activity prior to drowning among others. There is a need for more accurate exposure data (based on visitation information) to allow more sophisticated rates of river drowning per 100 000 visitations to be calculated. Most papers identified through this review focused on drowning overall, with only a small subsection of the paper including data and risk factors specific to rivers.

The sphere of river drowning prevention would also benefit from the use of an agreed definition to allow comparison across studies. Further specificity is required within coding mechanisms for location that go beyond the current coding structures within the ICD codes for location of drowning.

Limitations

- ▶ No papers identified in this systematic review included a rate per 100 000 for river drowning. Where a general rate of drowning per 100 000 and a proportion of drowning deaths in rivers was included in the paper, we were able to calculate a crude rate of river drowning per 100 000 people. These crude drowning rates are not age adjusted and may not be as accurate if calculated from primary data. It does, however, for the first time provide a comparison between papers.
- ▶ Although the English language limit was used, the search did identify papers (three) where the abstract was in the English language, but the full paper was in a language other than English (Portuguese, Chinese and Turkish). Of these, only one paper identified the burden of river drowning, accounting for 6.3% of drowning in a tourism region of Turkey between 2002 and 2006.⁷⁴ These three studies were found as part of the overall 895 papers, but were excluded on the basis of not being in the English language.
- ▶ The majority of the papers included in this review are from HICs, with only four papers from three LMICs (China, Iran and Bangladesh) being deemed to fit the inclusion criteria.
- ▶ This systematic review excluded grey literature (ie, non-peer-reviewed literature such as research published by international, government and non-governmental organisations) and may not have identified all studies in the area, thus publication bias may be present.

CONCLUSION

This review found that the crude rate of river drowning ranged from 0.20 to 1.89 per 100 000 population and that common risk factors were being male, age, alcohol and rurality of river locations. Data coding limitations that restrict our ability to extract river drowning deaths from within the ICD code of

What is already known on the subject

- ▶ Fatal drowning is a global public health issue, with the WHO estimating 372 000 drowning deaths annually.
- ▶ Fatal river drowning is a hitherto little researched topic.
- ▶ Location-specific prevention efforts for drowning are likely to be more effective, as has been seen in the prevention of child drowning in private swimming pools.

What this study adds

- ▶ Calculated fatal crude river drowning rates ranged from 0.20 to 1.89 per 100 000 population.
- ▶ A range of risk factors are identified in the literature such as sex, age groups ranging from young children to older people, and the consumption of alcohol; however, there is little consensus.
- ▶ Gaps identified include the need for a consistently applied definition for rivers, the need for national population level studies into the prevalence and prevention of river drowning, studies on exposure patterns for rivers, and well-evaluated prevention strategies (commonly proposed strategies include wearing lifejackets, restricting access through fencing, supervision of children, and education about risk).

natural waterways makes identifying location-specific burden almost impossible.

This systematic review has identified that river drowning deaths are an issue in many regions and countries around the world. Further research is warranted, as well as the development, implementation and evaluation of prevention strategies. Future work should focus on the gaps identified in the research including: the development of an agreed definition; national population level studies into the prevalence of fatal river drowning; studies that quantify risk factors; studies that explore exposure; and studies that provide evidence for effective prevention.

Twitter Follow Richard Franklin at @Franklin_R_C, follow Amy E Peden at @amyepeden, follow Royal Life Saving at @RoyalLifeSaving

Acknowledgements This research is supported by the Royal Life Saving Society–Australia to aid in the reduction of drowning. Research at the Royal Life Saving Society–Australia is supported by the Australian Government.

Contributors AEP and RCF conceptualised and designed the study. AEP conducted the analysis, drafted the initial manuscript and approved the final manuscript as submitted. RCF carried out quality control of analysis, reviewed and revised the manuscript and approved the final manuscript submitted. PAL reviewed and revised the manuscript and approved the final manuscript as submitted.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

REFERENCES

- 1 World Health Organisation. *Global report on drowning: preventing a leading killer*. Geneva: World Health Organisation, 2014. http://apps.who.int/iris/bitstream/10665/143893/1/9789241564786_eng.pdf?ua=1&ua=1 (accessed 22 May 2015).
- 2 Lin C, Wang Y, Lu T, et al. Unintentional drowning mortality, by age and body of water: an analysis of 60 countries. *Inj Prev* 2015;21:e43–350.
- 3 Thompson DC, Rivara FP. Pool fencing for preventing drowning in children. *Cochrane Database Syst Rev* 2000;(2):CD001047. <http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD001047/pdf> (accessed 22 May 2015).
- 4 Franklin RC, Scarr JP, Pearn JH. Reducing drowning deaths: the continued challenge of immersion fatalities in Australia. *Med J Aust* 2010;192:123–6.
- 5 Nixon J, Pearn J, Wilkey I, et al. Fifteen years of child drowning—a 1967–1981 analysis of all fatal cases from the Brisbane drowning study and an 11 year study of consecutive near-drowning cases. *Accid Anal Prev* 1986;18:199–203.
- 6 Nixon JW, Pearn JH, Dugdale AE. Swimming ability of children: a survey of 4000 Queensland children in a high drowning region. *Med J Aust* 1979;2:271–2.
- 7 Pearn J, Nixon J. Swimming pool immersion accidents: an analysis from the Brisbane Drowning Study. *Med J Aust* 1977;1:432–7.
- 8 Bugeja L, Franklin RC. An analysis of stratagems to reduce drowning deaths of young children in private swimming pools and spas in Victoria, Australia. *Int J Inj Contr Saf Promot* 2013;20:282–94.
- 9 Morgan D, Ozanne-Smith J, Triggs T. Descriptive epidemiology of drowning deaths in a surf beach swimmer and surfer population. *Inj Prev* 2008;14:62–5.
- 10 Sherker S, Brander R, Finch C, et al. Why Australia needs an effective national campaign to reduce coastal drowning. *J Sci Med Sport* 2008;11:81–3.
- 11 Williamson A, Hatfield J, Sherker S, et al. A comparison of attitudes and knowledge of beach safety in Australia for beachgoers, rural residents and international tourists. *Aust N Z Health J Public Health* 2012;36:385–91.
- 12 National Centre for Classification in Health Australia. *ICD-10-AM tabular list of diseases*. Sydney: National Centre for Classification in Health, Australia, 2004.
- 13 ICECI Coordination and Management Group. *International Classification of External Causes of Injuries (ICECI) version 1.2*. Adelaide: Consumer Safety Institute, Amsterdam and AIHW National Injury Surveillance Unit, 2004.
- 14 Soko B. *Fiji Drowning Report 2012: Water Safety Council of Fiji, 2013*. http://watersafety.org.fj/wp-content/uploads/2014/11/Fiji-Drowning-Report-2012_LR-FINAL-20130626.pdf (accessed 1 Jun 2015).
- 15 Rahman A, Mashreky SR, Chowdhury SM, et al. Analysis of the childhood fatal drowning situation in Bangladesh: exploring prevention measures for low-income countries. *Inj Prev* 2009;15:75–9.
- 16 Statens Institut for Folkesundhed. *Denmark National Drowning Report 2001–2012*. 2014.

- 17 Linnan M, Rahman A, Scarr J, et al. *Child Drowning: Evidence for a newly recognized cause of child mortality in low and middle income countries in Asia*. Working Paper 2012–07, Special Series on Child Injury No 2 Florence: UNICEF Office of Research, 2012. <http://www.unicef-irc.org/publications/pdf/drowning.pdf> (accessed 1 Jun 2015).
- 18 Buzzacott P, Rosenberg M, Pikora T. Western Australian recreational scuba diving fatalities, 1992 to 2005. *Aust N Z J Public Health* 2009;33:212–4.
- 19 Johnston BD. Prevention of open water drowning while boating. *Inj Prev* 2014;20:219–9.
- 20 Pitt R, Balanda KP. Childhood drowning and near-drowning in Brisbane: the contribution of domestic pools. *Med J Aust* 1991;154:661–5.
- 21 Royal Life Saving Society—Australia. *Royal Life Saving National Drowning Report 2011*. Sydney: Royal Life Saving Society—Australia, 2011. http://www.royallifesaving.com.au/_data/assets/pdf_file/0005/4001/2011-Drowning-Report.pdf (accessed 25 May 2015).
- 22 Royal Life Saving Society—Australia. *Royal Life Saving National Drowning Report 2012*. Sydney: Royal Life Saving Society—Australia, 2012. http://www.royallifesaving.com.au/_data/assets/pdf_file/0006/4002/2012-Drowning-Report.pdf (accessed 25 May 2015).
- 23 Royal Life Saving Society—Australia. *Royal Life Saving National Drowning Report 2013*. Sydney: Royal Life Saving Society—Australia, 2013. http://www.royallifesaving.com.au/_data/assets/pdf_file/0003/9759/RLS_NationalDrowningReport_2013.pdf (accessed 25 May 2015).
- 24 Royal Life Saving Society—Australia. *Royal Life Saving National Drowning Report 2014*. Sydney: Royal Life Saving Society—Australia, 2014. http://www.royallifesaving.com.au/_data/assets/pdf_file/0007/11995/RLS_NDR2014_LR.pdf (accessed 25 May 2015).
- 25 Australian Water Safety Council. *Australian water safety strategy 2008–11*. Sydney: Australian Water Safety Council, 2008. <http://www.watersafety.com.au/Portals/0/AWSC%20Strategy%202012-15/AWSC%20Strategy%202008-2011/Australian%20Water%20Safety%20Strategy%202008-11.pdf> (accessed 25 May 2015).
- 26 Australian Water Safety Council. *Australian water safety strategy 2012–15*. Sydney: Australian Water Safety Council, 2012. http://www.watersafety.com.au/Portals/0/AWSC%20Strategy%202012-15/AWSC_Strategy2012_Brochure%20-%20Lowres.pdf (accessed 25 May 2015).
- 27 van Beek E, Branche CM, Szpilmann D, et al. A new definition of drowning: towards documentation and prevention of a global public health problem. *Bull World Health Organ* 2005;83:853–6.
- 28 Wilson I, McDermott H, Munir F, et al. Injuries, ill-health and fatalities in white water rafting and white water paddling. *Sports Med* 2013;43:65–75.
- 29 Jonkman SN, Kelman I. An analysis of the causes and circumstances of flood disaster deaths. *Disasters* 2005;29:75–97.
- 30 Davis S, Ledman J, Kilgore J. Drownings of children and youth in a desert state. *West J Med* 1985;143:196–201.
- 31 Porta M. *A dictionary of epidemiology*. 4th edn. Oxford University Press, 2008.
- 32 Royal Life Saving Drowning Database Definitions and Coding Manual. In: Peden AE, ed. Sydney: Royal Life Saving Society—Australia, 2014:p41–42.
- 33 Australian Water Safety Council. *A guide to water safety essentials for local governments*. Sydney, 2008. <http://www.watersafety.com.au/Reports.aspx> (accessed 28 May 2015).
- 34 Brenner RA, Trumble AC, Smith GS, et al. Where children drown, United States, 1995. *Pediatrics* 2001;108:85–9.
- 35 Byard RW, Lipsett J. Drowning deaths in toddlers and preambulatory children in South Australia. *Am J Forensic Med Pathol* 1999;20:328–32.
- 36 Cass D, Ross F, Grattan-Smith T. Child drownings: a changing pattern. *Med J Aust* 1991;154:163–5.
- 37 Cass DT, Ross F, Lam LT. Childhood drowning in New South Wales 1990–1995: a population-based study. *Med J Aust* 1996;165:610–12.
- 38 Dietz PE, Baker SP. Drowning: epidemiology and prevention. *Am J Public Health* 1974;64:303–12.
- 39 Fang Y, Dai L, Jaung MS, et al. Child drowning deaths in Xiamen city and suburbs, People's Republic of China, 2001–5. *Inj Prev* 2007;13:339–43.
- 40 Fife D, Scipio S, Crane GL. Fatal and nonfatal immersion injuries among New Jersey residents. *Am J Prev Med* 1991;7:189–93.
- 41 Franklin RC, Mitchell RJ, Driscoll TR, et al. Non-work-related farm fatalities in Australia, 1989–1992. *J Agric Saf Health* 2001;7:229–39.
- 42 Iqbal A, Shirin T, Ahmed T, et al. Childhood mortality due to drowning in rural Matlab of Bangladesh: magnitude of the problem and proposed solutions. *J Health Popul Nutr* 2007;25:370–6.
- 43 Kiakalayeh AD, Mohammadi R, Ekman DS, et al. Unintentional drowning in northern Iran: a population-based study. *Accid Anal Prev* 2008;40:1977–81.
- 44 Lunetta P, Smith GS, Penttilä A, et al. Unintentional drowning in Finland 1970–2000: a population-based study. *Int J Epidemiol* 2004;33:1053–63.
- 45 Newman LM, Diekema DS, Shubkin CD, et al. Pediatric wilderness recreational deaths in western Washington State. *Ann Emerg Med* 1998;32:687–92.
- 46 O'Hare D, Chalmers D, Arnold NA, et al. Mortality and morbidity in white water rafting in New Zealand. *Inj Control Saf Promot* 2002;9:193–8.
- 47 Patetta MJ, Biddinger PW. Characteristics of drowning deaths in North Carolina. *Public Health Rep* 1988;103:406–11.
- 48 Riley MD, Larson A, Langford J. Drowning fatalities of children in Tasmania: differences from national data. *Aust N Z J Public Health* 1996;20:547–9.
- 49 Tan RMK. The epidemiology and prevention of drowning in Singapore. *Singapore Med J* 2004;45:324–9.
- 50 Wentworth P, Croal AE, Jentz LA, et al. Water-related deaths in Brant County 1969–1992: A review of fifty-seven cases. *J Can Soc Forensic Sci* 1993;26:1–18.
- 51 Ahmed MK, Rahman M, van Ginneken J. Epidemiology of child deaths due to drowning in Matlab, Bangladesh. *Int J Epidemiol* 1999;28:306–11.
- 52 Howland J, Mangione T, Hingson R, et al. A pilot survey of aquatic activities and related consumption of alcohol, with implications for drowning. *Public Health Rep* 1990;105:415–9.
- 53 Kauffman RB. The drowning trap: on the Potomac River most people drown well below flood levels. *Trends* 1992;29:39–47.
- 54 Sorey WH, Cassidy LD, Crout J, et al. River tree rope swing injuries. *South Med J* 2008;101:699–702.
- 55 Australian Government National Health and Medical Research Council (NHMRC). NHMRC additional levels of evidence and grades for recommendations for developers of guidelines. Secondary NHMRC additional levels of evidence and grades for recommendations for developers of guidelines 2005. http://www.nhmrc.gov.au/_files_nhmrc/file/guidelines/levels_grades05.pdf
- 56 Mahabalesh S. Profile of drowning deaths in Mangalore, a coastal city of Karnataka. *Med-Leg Update* 2005;5:39–42.
- 57 Seleye-Fubara D, Nicholas EE, Esse I. Drowning in the Niger Delta region of Nigeria: an autopsy study of 85 cases. *Niger Postgrad Med J* 2012;19:111–4.
- 58 Nichter MA, Everett PB. Profile of drowning victims in a coastal community. *J Fla Med Assoc* 1989;76:253–6.
- 59 Rathod H, Pathak A, Mangal HM. Epidemiological study of drowning deaths in Rajkot, Gujarat. *J Forensic Med Toxicol* 2008;25:1–4.
- 60 Rodrigues EJ. Medico legal study of drowning cases in Goa Medical College Hospital, Bambolim, Goa. *Int J Med Toxicol Legal Med* 2006;8:7–10.
- 61 Suresh Kumar Shetty B, Shetty M. Epidemiology of drowning in Mangalore, a coastal Taluk of South India. *J Forensic Leg Med* 2007;14:410–15.
- 62 Kemp A, Sibert JR. Drowning and near drowning in children in the United Kingdom: lessons for prevention. *BMJ* 1992;304:1143–6.
- 63 Wallis B, Watt K, Franklin RC, et al. Out of sight but not out of mind: rural drowning in Queensland. *Inj Prev* 2012;18(Suppl 1):A136.
- 64 Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009;339:b2535.
- 65 Wintemute GJ, Anton A, Andrada E, et al. Compliance with an ordinance requiring the use of personal flotation devices by children in public waterways. *West J Emerg Med* 2013;14:200–3.
- 66 Moran K. Jumping to (fatal) conclusions? An analysis of video film on a social networking web site of recreational jumping from height into water. *Int J Inj Contr Saf Promot* 2014;21:47–53.
- 67 Nakahara S, Ichikawa M, Wakai S. Drowning deaths among Japanese children aged 1–4 years: different trends due to different risk reductions. *Inj Prev* 2004;10:125–6.
- 68 Kanchan T, Monteiro FNP. An analysis of accidental drowning fatalities in Manipal, South India. *Inj Prev* 2012;18(Suppl 1):A132.
- 69 Lasbeur L, Girard D, Thelot B. Epidemiological surveillance of drownings: a national survey in France, 1 June–30 September 2009. *Inj Prev* 2010;16:A125.
- 70 Rolloque A, Consunji RJ, Perez MT, et al. Cutcut project: a response to the prevention of child drowning in the Philippines. *Inj Prev* 2012;18(Suppl 1):A132.
- 71 Morrongiello BA, Pickett W, Berg RL, et al. Adult supervision and pediatric injuries in the agricultural worksite. *Accid Anal Prev* 2008;40:1149–56.
- 72 Saluja G, Brenner R, Morrongiello BA, et al. The role of supervision in child injury risk: definition, conceptual and measurement issues. *Inj Control Saf Promot* 2004;11:17–22.
- 73 Mitchell R, Haddrill K. From the bush to the beach: water safety in rural and remote New South Wales. *Aust J Rural Health* 2004;12:246–50.
- 74 Lakadamyali H, Doğan T. Investigation of drowning cases in a tourism region of Turkey. *Turk Klinikleri J Med Sci* 2008;28:143–8.

Figure 1: Modified PRISMA flow chart ⁷⁶ - Process for extracting relevant papers (N=29)

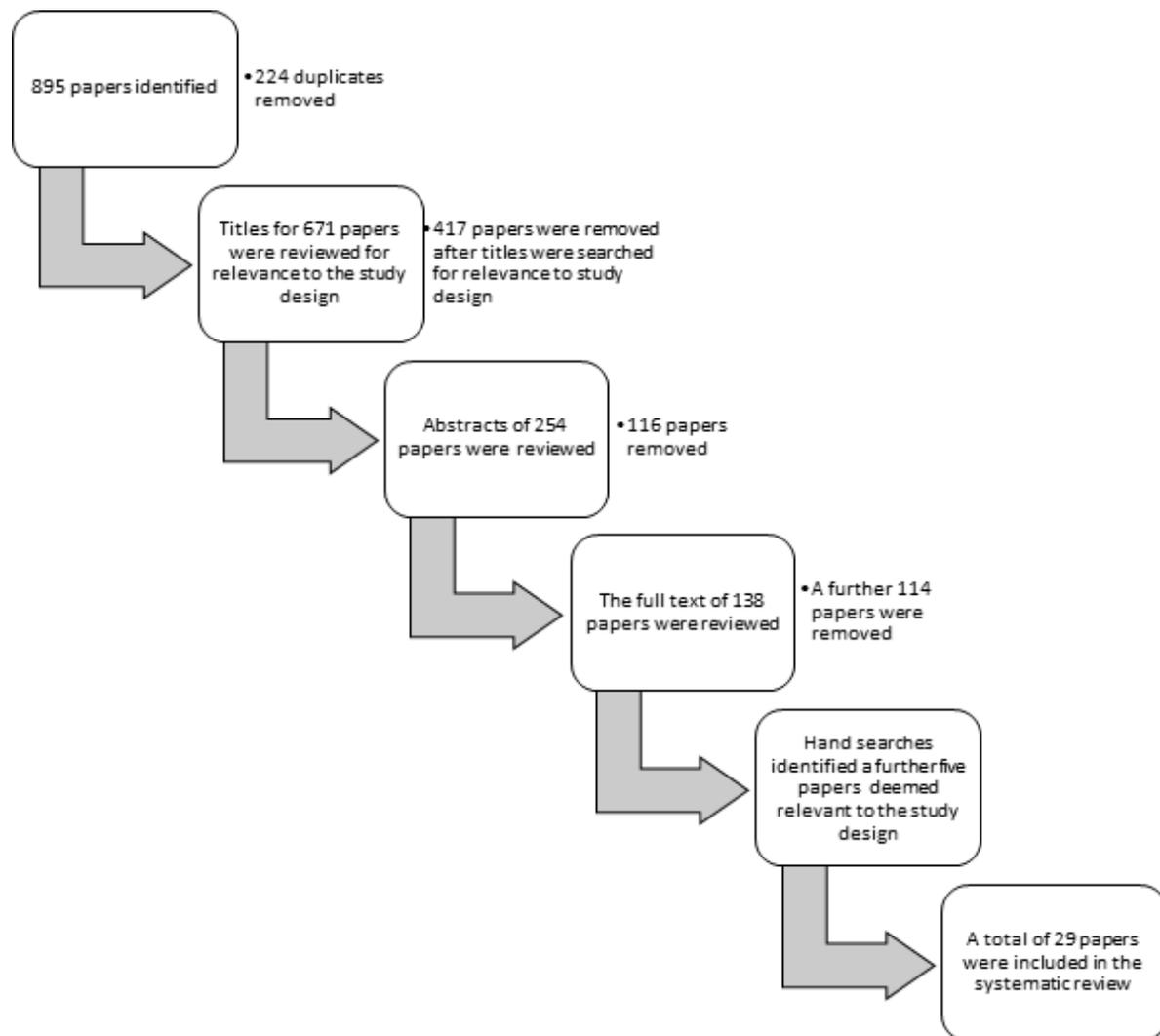


Table 1a: Search methodology including databases used, search terms used and results

Search Number	Search Term	Number Found
MEDLINE		
1	Drown* (no limits)	4803
2	Drown* with limits of English language, human, 1980-2014	2904
3	River* (no limits)	37555
4	Stream* (no limits)	33389
5	Creek* (no limits)	1947
6	Fresh water (no limits)	27018
7	Combined 2-6 OR	92345
8	Combined 7 AND 2	195
SCOPUS		
	TITLE-ABS-KEY (drown*) AND PUBYEAR > 1979 AND PUBYEAR < 2015 AND (TITLE-ABS-KEY (river*) OR TITLE-ABS-KEY (stream*) OR TITLE-ABS-KEY (creek*) OR TITLE-ABS-KEY (fresh water)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO(SUBJAREA, "MEDI") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "NURS") OR LIMIT-TO (SUBJAREA, "PHAR") OR LIMIT-TO (SUBJAREA, "HEAL") OR LIMIT-TO (SUBJAREA, "MULT") OR LIMIT-TO(SUBJAREA, "PSYC"))	376
PSYCHINFO		
	Drown* and river* OR steam* OR creek* OR fresh water (no limits)	1784
	Drown* and river* OR steam* OR creek* OR fresh water (limited to Peer reviewed and 1 January 1980 to 31 December 2014)	1111
	Drown* and river* OR steam* OR creek* OR fresh water (limited to Peer reviewed and 1 January 1980 to 31 December 2014 and human and English language)	942
	OR Drown* AND (river* OR stream* OR creek* OR fresh water)	14
SCIENCEDIRECT		
	pub-date > 1979 and pub-date < 2015 and DROWN* and (RIVER* OR CREEK* OR STREAM* OR FRESH WATER) AND LIMIT-TO(topics, "child, patient, drowning, cardiac arrest, usa, climate change ,post mortem, south china, north atlantic, cpr, emergency medicine, estuary, salt marsh") AND LIMIT-TO(cids, "271258,271105,272873,272201,271781,272396,272456,271861,273471,273323,271742,271759","Forensic Science International, Resuscitation, Annals of Emergency Medicine, Legal Medicine, Marine Geology, Estuarine, Coastal and Shelf Science, The American Journal of Emergency Medicine, Quaternary Science Reviews, Encyclopedia of Forensic and Legal Medicine, Pediatric Clinics of North America, Ecological Engineering, Global and Planetary Change").	159
SPORTSDISCUSS		
	Drown* (TX All Text) AND river* OR stream* OR creek* (TX All Text) limits to (1 Jan 1980 to 31 Dec 2014). Language English. Search modes – BooleanPhrase	50
COCHRANE.ORG		
	The term river was entered which produced 4 papers, of which 1 was deemed relevant	1
SAFETY LIT		
	Textword + synonyms searched using terms Drown* and river* OR creek* OR stream*(limits 1980 to 2014, All publication types, limited to English language)	100

Table S1b: List of References Deemed Relevant to Study Design of Systematic Literature Review (N=29)

	Reference	Reference number in text
1	Ahmed MK, Rahman M, van Ginneken J. Epidemiology of child deaths due to drowning in Matlab, Bangladesh. International Journal of Epidemiology 1999; 28 (2):306-11.	51
2	Brenner RA, Trumble AC, Smith GS, et al. Where Children Drown, United States, 1995. Pediatrics 2001; 108 (1):85-89.	34
3	Byard RW, Lipsett J. Drowning deaths in toddlers and preambulatory children in South Australia. American Journal of Forensic Medicine & Pathology 1999; 20 (4):328-32.	35
4	Cass D, Ross F, Grattan-Smith T. Child drownings: a changing pattern. Medical Journal of Australia 1991; 154 (3):163-5.	36
5	Cass DT, Ross F, Lam LT. Childhood drowning in New South Wales 1990-1995: a population-based study. Medical Journal of Australia 1996; 165 (11-12):610-2.	37
6	Davis S, Ledman J, Kilgore J. Drownings of children and youth in a desert state. Western Journal of Medicine 1985; 143 (2):196-201.	30
7	Dietz PE, Baker SP. Drowning: Epidemiology and prevention. Am J Public Health 1974; 64 (4):303-12.	38
8	Fang Y, Dai L, Jaung MS, et al. Child drowning deaths in Xiamen city and suburbs, People's Republic of China, 2001-5. Injury Prevention 2007; 13 :339-43.	39
9	Fife D, Scipio S, Crane GL. Fatal and nonfatal immersion injuries among New Jersey residents. American Journal of Preventive Medicine 1991; 7 (4):189-93.	40
10	Franklin RC, Mitchell RJ, Driscoll TR, et al. Non-work-related farm fatalities in Australia, 1989-1992. J Agric Saf Health 2001; 7 (4):229-39.	41
11	Franklin RC, Scarr JP, Pearn JH. Reducing drowning deaths: the continued challenge of immersion fatalities in Australia. Medical Journal of Australia 2010; 192 (3):123-6.	4
12	Howland J, Mangione T, Hingson R, et al. A pilot survey of aquatic activities and related consumption of alcohol, with implications for drowning. Public Health Reports 1990; 105 (4):415-9.	52
13	Iqbal A, Shirin T, Ahmed T, et al. Childhood mortality due to drowning in rural Matlab of Bangladesh: magnitude of the problem and proposed solutions. J Health Popul Nutr 2007; 25 (3):370-6.	42
14	Kauffman RB. The drowning trap: on the Potomac River most people drown well below flood levels. Trends 1992; 29 (1):39-47.	53
15	Kemp A, Sibert JR. Drowning and near drowning in children in the United Kingdom: lessons for prevention. BMJ 1992; 304 (6835):1143-6.	62
16	Kiakalayeh AD, Mohammadi R, Ekman DS, et al. Unintentional drowning in northern Iran: a population-based study. Accid Anal Prev 2008; 40 (6):1977-81	43
17	Lunetta P, Smith GS, Penttilä A, et al. Unintentional drowning in Finland 1970-2000: a population-based study. International Journal of Epidemiology 2004; 33 (5):1053-63.	44
18	Moran K. Jumping to (fatal) conclusions? An analysis of video film on a social networking web site of recreational jumping from height into water. Int J Inj Contr Saf Promot 2014; 21 (1):47-53.	66

19	Nakahara S, Ichikawa M, Wakai S. Drowning deaths among Japanese children aged 1-4 years: different trends due ot different risk reductions. <i>Injury Prevention</i> 2004; 10 (2):125-26.	67
20	Newman LM, Diekema DS, Shubkin CD, et al. Pediatric wilderness recreational deaths in western Washington State. <i>Annals of Emergency Medicine</i> 1998; 32 (6):687-92.	45
21	Nixon J, Pearn J, Wilkey I, et al. Fifteen years of child drowning- A 1967-1981 analysis of all fatal cases from the Brisbane drowning study and an 11 year study of consecutive near-drowning cases. <i>Accident Analysis and Prevention</i> 1986; 18 (3):199-203.	5
22	O'Hare D, Chalmers D, Arnold NA, et al. Mortality and morbidity in white water rafting in New Zealand. <i>Inj Control Saf Promot</i> 2002; 9 (3):193-8.	46
23	Patetta MJ, Biddinger PW. Characteristics of drowning deaths in North Carolina. <i>Public Health Reports</i> 1988; 103 (4):406-11.	47
24	Rahman A, Mashreky SR, Chowdhury SM, et al. Analysis of the childhood fatal drowning situation in Bangladesh: exploring prevention measures for low income countries. <i>Injury Prevention</i> 2009; 15 (2):75-79.	15
25	Riley MD, Larson A, Langford J. Drowning fatalities of children in Tasmania: differences from national data. <i>Aust N Z J Public Health</i> 1996; 20 (5):547-9.	48
26	Sorey WH, Cassidy LD, Crout J, et al. River tree rope swing injuries. <i>Southern Medical Journal</i> 2008; 101 (7):699-702.	54
27	Tan RMK. The epidemiology and prevention of drowning in Singapore. <i>Singapore Medical Journal</i> 2004; 45 (7):324-9.	49
28	Wentworth P, Croal AE, Jentz LA, et al. Water-related deaths in Brant County 1969-1992: A review of fifty-seven cases. <i>J CAN SOC FORENSIC SCI</i> 1993; 26 (1):1-18.	50
29	Wintemute GJ, Anton A, Andrada E, et al. Compliance with an ordinance requiring the use of personal flotation devices by children in public waterways. <i>West J Emerg Med</i> 2013; 14 (2):200-03.	65