Interventions associated with drowning prevention in children and adolescents: Systematic literature review

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Interventions associated with drowning prevention in children and adolescents: systematic literature review

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ABSTRACT

Introduction Drowning remains a leading cause of preventable death in children across the world. This systematic review identifies and critically analyses studies of interventions designed to reduce fatal and non-fatal drowning events among children and adolescents or reduce the injury severity incurred by such incidents.

Methods A systematic search was undertaken on literature published between 1980 and 2010 relating to interventions around fatal and non-fatal drowning prevention in children and adolescents 0–19 years of age. Search methods and protocols developed and used by the WHO Global Burden of Disease Injury Expert Group were applied.

Results Seven studies fulfilled the inclusion criteria. Interventions were categorised into three themes of Education, Swimming Lessons and Water Safety, and Pool Fencing. All are possible effective strategies to prevent children from drowning, particularly young children aged 2–4 years, but very little evidence exists for interventions to reduce drowning in older children and adolescents. There were methodological limitations associated with all studies, so results need to be interpreted in the context of these.

Conclusions Relatively few studies employ rigorous methods and high levels of evidence to assess the impact of interventions designed to reduce drowning. Studies are also limited by lack of consistency in measured outcomes and drowning terminology. Further work is required to establish efficacy of interventions for older children and adolescents. There is a need for rigorous, well-designed studies that use consistent terminology to demonstrate effective prevention solutions.

INTRODUCTION

Drowning is a global problem, and drowning prevention is a worldwide challenge. It is a leading cause of death in young children in most industrialised countries of the world. Current estimates suggest that there are 175 000 child deaths annually,[1] although this is thought to be underestimated as it does not include drowning from transport, floods and cataclysms of nature and intentional drowning.[2]

Drowning is rarely the result of a single cause, nor is there a single prevention solution.[3 4] Circumstances can vary widely by age and aquatic setting,[5–7] and the activity being undertaken prior to drowning. In high-income countries (HIC), among children up to the age of 1 year, most drowning deaths occur in bathtubs.[6 8 9] However, when the child becomes progressively mobile after the first year of life, swimming pools and man-made ponds (dams) or reservoirs are more frequently involved.[10] Pivotal to any prevention effort is an understanding of where, how and why drowning occurs within that sequence of events, and what associated factors may affect the outcome.[11] Consequently, any prevention effort must take into account risk factors such as age, aquatic location, behaviour, proximity of water, social and physical environmental factors.

This systematic review aims to identify and critically analyse studies of interventions designed to reduce drowning events in children and adolescents aged 0–19 years or reduce the injury severity incurred by such incidents.

METHODS

Search methods and protocols developed and used by the WHO Global Burden of Disease Injury Expert Group in their revision of estimates of the burden of fatal and non-fatal injury were applied to this study.[12 13] The search procedure was adapted to facilitate our focus on intervention studies. A modified version of the PRISMA flow chart (PRISMA, 2011) was used to graphically articulate the search results (figure 1).

Literature published in the English language between 1980 and 2010 were searched using Medline; Embase, PsychInfo and SportsDiscuss and the Cochrane Central Register for Controlled Trials. Initial search terms were "drown*" and "human"—these were deliberately broad and were not qualified by publication type or methodology to ensure that all relevant articles could be located. A manual search was completed for all references retained for data extraction. Investigators did not search grey literature, and only peer-reviewed literature with primary data was included.

Four reviewers used standardised criteria to identify potentially eligible articles. Titles and abstracts were first screened by two reviewers (KW, RF). The full paper for 47 articles was assessed against the inclusion and exclusion criteria by three reviewers. The full text of potentially relevant articles was retrieved and reviewed by a further two reviewers (MT, BW), and where there were inconsistencies regarding inclusion, the paper was independently assessed by a third reviewer (KW) and consensus achieved. Papers were assessed according to the following inclusion criteria:

(1) Data from primary analytic studies that included a control or comparison group, where an

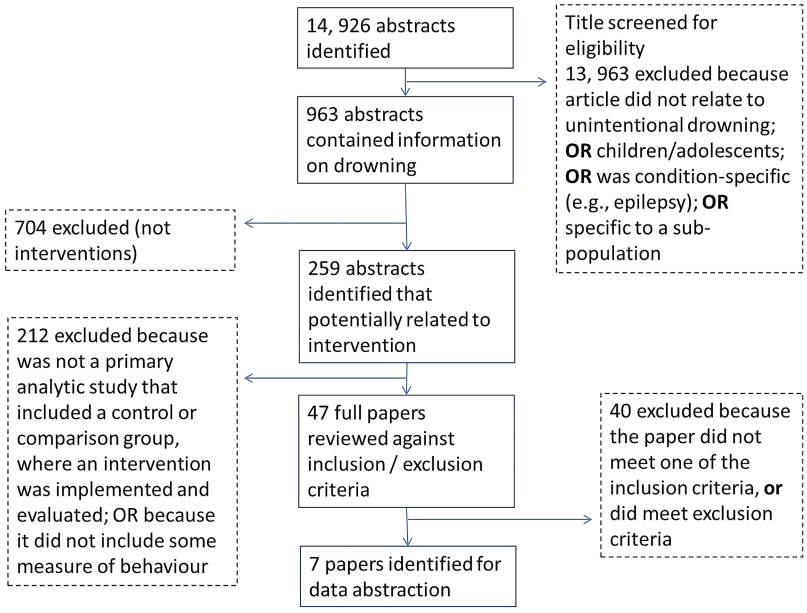

Figure 1 Process for extracting relevant articles.

intervention was implemented and evaluated; (2) some measure of behaviour was included (this did not have to be objective)—thus studies that included only measures of attitudes/knowledge were excluded; and (3) drowning event was unintentional; (4) sample comprised children and adolescents aged 0–19 years or at least 75% of the sample or data specifically related to 0–19 years and was presented separately for that age range. Articles that related to condition-specific drowning events such as epilepsy or seizure were excluded, as were articles that related to specific sub-populations such as occupational injury commercial fishermen, SCUBA, snorkelling, caving and diving, air crashes, wilderness workers, hurricanes and tsunami.

The data extraction form used to assess the methodological quality of articles for the purpose of this review is available from the authors upon request. It included study design, number, characteristics and recruitment of participants, geographical location of study, aims of the research, methodology, nature of intervention, outcome measures, main findings and methodological limitations (e.g. sources of bias). The studies were analysed according to their characteristics, measures, results and study quality. Study quality included issues related to study design, sample (composition and size), measurements and potential biases affecting validity. Level of evidence was also assessed.[14 15]

RESULTS

Initial searches identified 14 926 papers from which 963 were identified as potentially relevant after reading title only. Of these 963 articles, 704 were excluded because they did not relate to interventions. Abstracts of the remaining 259 papers were assessed against the inclusion and exclusion criteria, and 212 were excluded, primarily because they did not fulfil either or both inclusion criteria 1 and 2. The full paper for 47 articles was assessed against the inclusion and exclusion criteria.

Seven articles were retained for inclusion in the review. The process for retention of seven articles is outlined in figure 1.

Seven studies met the inclusion criteria[16–22] and are described in tables 1–3 under the themes of Education, Swimming and Water Safety, and Pool Fencing. Characteristics of the included studies, and the level of evidence yielded by the study, are also presented.

There were two randomised controlled trials with control groups[19 22]; and one without[16]; three case–control studies[18 20 21]; and one evaluation of a community awareness campaign (pre-post study).[17] Six of the articles were from the USA[16–20 22] and one from Australia.[21]

The most common age group targeted in the studies of 0–19 year olds included in this review was 0–4 years —all but one study examined this age group. An intervention[19] specifically designed for school-age children in the USA and delivered in school setting to grades 1, 2 and 3 was the only exception. Ages of children included in the study were not specified; however, children in grades 1–3 are likely to be aged 6–9 years.[23] In three papers,[20–22] children aged less than 1 year old were included as part of an overall age group up to age 13 years. Only one study[18] included adolescents beyond 14 years.

Education on injury prevention

Educational interventions are designed to teach a specific group to either increase their knowledge about hazards, consequences and possible solutions, or to attempt to achieve a behaviour change within the target group.

Of the three studies (table 1) that used education interventions, two were randomised controlled trials,[19 22] and the third was a community-wide awareness campaign.[17] Drowning fatalities were an objective measure in one study.[17] However, the number of drowning events did not change significantly during the study period, and numbers were too small to definitively assess between-group differences.

Two interventions contained drowning prevention as part of an overall injury prevention programme where drowning was one of many possible causes of trauma or injury topics.[19 22] The studies delivered programmes in specific settings to reach the selected target age groups. One intervention was delivered to parents of infants and toddlers who presented at an emergency department (ED) with an unintentional injury[22] and the other was delivered to children aged 6–8 years within the school setting.[19] The third study was an awareness campaign that focused only on drowning prevention and promoted life

Table 1 Effectiveness of drowning interventions using education (included studies)

Interventions				
Study characteristics (quality)	**Intervention description**	**Key elements**	**Measures**	**Results**
Bennett et al, 1999[17]: *Life Vest community-wide awareness campaign and evaluation*				
Pre-post Evidence level: III-3 No control Parents of children 1–14 years USA	Media awareness campaign and evaluation county-wide over three summers 1992–1994 (print, promotions and special events). Life Vest retail programme (discount and loan options) Telephone surveys at baseline (n=332), twice during (n=400 each) and once after (n=480).	Messages: "Wear a life vest" "Supervise children around water" "Learn guidelines for water safety" Community-wide Evaluation: recall of campaign messages during and 12 months after campaign	Self-report knowledge surveys by telephone. Life vest ownership and use at beach/pool/boats. Drowning fatality rates. 3 years prior to vs 3 years during campaign. Other variables: Demographics, parent confidence. child swimming ability, perceived susceptibility of child to drowning, perceived life vest efficacy.	Life vest ownership 11% (95% CI 3% to 17%).* Life vest use (OR=1.6; 95% CI 1.1 to 2.5) (self-reported).* Drowning fatalities: 12 deaths in 3 years among 1–14 years prior to campaign, and 8 deaths in 3 years during campaign (inc bathtubs).† Life vest use significantly associated with: child ownership of a vest (OR=2.6 95% CI 1.5 to 4.4) parent <40 years (OR=2.3 95% CI 1.5 to 3.6) child's poor swimming ability (OR=1.6 95% CI 1.1 to 2.4) parent confident fitting a vest (OR=3.2 95% CI 1.5 to 7) parent recalling campaign (OR=1.6 95% CI 1.1 to 2.5).
Gresham et al, 2001[19] *Injury prevention curriculum delivered in schools—water safety component only*				
Randomised controlled trial (RCT) Evidence level: II Intervention vs no intervention Grades 1–3 (6–9 years) USA	Integrated curricula and evaluation on injury and risk behaviour. Classroom delivery over 6-week period in fall 1997. 15 schools (8 intervention and 7 control), randomly allocated to control (n=1126) or Intervention (n=851) matched on SES, reading scores and race.	Trained teachers and school nurses delivered 6-week injury prevention curriculum. Water safety one of 6 topics. Self-report pre- and postintervention surveys.	Self-report knowledge surveys completed at school within 10 days. Knowledge of hazard of brain and spinal cord injury in different bodies of water. Knowledge of safety rules.Awareness of preventing water-related injury and drowning. Individual responsibility in prevention.	Water safety knowledge improved from pre- to postintervention (p<0.01 for each grade).* Note: self-report rather than injury reduction or observation. Contamination possible through community activities and media.
Posner et al, 2004[22] *Injury prevention home-based safety information for parents attending ED*				
RCT Evidence level: II Intervention vs no intervention Parents of children <5 years USA	Child presentations to ED with unintentional injury sustained at home September–December 2001. Randomly assigned to (intervention=49; control=47) Telephone survey 2months after ED visit.	Trained RAs delivered to caregivers, usual care (injury focused) vs comprehensive home safety education. Drowning one of 7 topics), a free home safety kit (a non-slip bath decal was the only water safety related device).	Knowledge of caregivers surveyed on 51-item multichoice home safety questionnaire to obtain overall safety score. (submersion category=4 items). Other: demographics and injury characteristic information.	No significant improvement (p>0.05) observed for drowning prevention.† Significant improvement (p<0.01) in overall safety scores in intervention group vs control group, attributed to increase in use of safety devices (p<0.001).* Self-reported use.

*Statistically significant association.
†No association not statistically significant.
ED, emergency department; SES, socioeconomic status.

Table 2 Effectiveness of drowning interventions using swimming lessons and water safety (included studies)

Interventions				
Study characteristics (quality)	**Intervention description**	**Key elements**	**Measures**	**Results**
Asher et al[16] *Water safety training and swimming lessons*				
Randomised trial no control Evidence level: III-3 Swimming skills and water safety in two groups 24–42 months USA	Swimming skills and water safety lessons delivered in two groups twice weekly for 8 weeks (n=48) or 12 weeks (n=61) duration. Participants recruited by letters sent to Child Care Centres located near public pools in middle-income Seattle area 1990s.	Trained instructors. Lessons adapted from American Red Cross programme Instruction provided in groups of six children in pool with parent. Lesson time not published. Evaluation by blinded observers and follow-up phone calls over 18-month period. Participants offered $50.	Three skills sets: 1. Out of water safety behaviour (deck behaviour—e.g. running around pool, pushing others, entering water without an adult). 2. Swimming ability (face underwater, recover from prone, roll back to front, propulsive kicking, beginner stroke, independently enter and exit pool, jump into pool independently). 3. In-water safety skills (water recovery ability to stand up when dropped from above water and ability to jump in and swim to edge of pool). Swimming ability assessed by instructors. Water safety skills measured by independent blinded observers (instructors) four times in two groups. Self-report surveys for parental demographics and child development.	Evidence that swimming lessons improve swimming ability in children aged 2–3 years. Swimming ability significantly improved in both 8- and 12-week groups p<0.001* Deck behaviour not improved p<0.03.† Water recovery showed significant improvement in both groups p<0.001.* Jump and swim improved over time in both groups p<0.005.* No control group—effect could be explained by water familiarity. Impact of skills effecting parent vigilance not studied and no children <2 years. Recommends swimming part of comprehensive approach including barriers, PFDs adult supervision and safety awareness. Found no support for concern that water safety instruction increases young children's risk of drowning Incentive payment. Simulated risk as proxy for drowning. No children <24 months included.
Brenner et al[18] *Swimming lessons (formal and informal) and drowning assessed*				
Case–control population-based Evidence level: III-2 Formal lessons vs informal/no lessons 1–19 years USA	Fatal drowning among 1–19 years, April 2003–September 2005 (2.5 years). Cases (n=88) (1–4 years n=61; and 5–19 years n=27) fatalities identified from Coroner's data. Controls (n=213) matched to cases on age, sex, residence and presence of pool at their home. Telephone interviews by random digit dialling or mail with next of kin. $25 inducement fee paid to participants.	Formal and informal swimming lessons assessed for association with fatal drowning. Definitions: Formal lessons: child received paid lessons or through day care, school or camp. Informal lessons: child not received pointers about swimming or water safety. Non swimmers: no exposure to water or pointers or tips.	Outcome fatal drowning. Exposure to water (≤1 time, or more), swimming ability (Y/N float on back, float on stomach, jump in pool and swim 5 ft back to wall), participation in formal and informal swimming lessons (Y/N). Parental self-report child development, temperament (1–4 years), risk taking, medical conditions and household characteristics.	Swimming lessons: 1–4 years. Cases less likely than controls 3% vs 26% to have participated in previous formal swimming lessons (adjusted OR=0.12 95% CI 0.01 to 0.97).‡ No significant association between formal swimming lessons and drowning in older children 5–19 years (OR=0.36, 95% CI 0.01 to 1.51)† No significant associations were observed between informal swimming instruction and drowning in either age group. *1–4 years*: cases less skilled at floating on back for 10 s 5% vs 18% controls p=0.01‡ Cases were also more likely to be non-white p=0.4; low income p=0.03, low education p=0.003; risk takers p=0.03; temperament p=0.06; other medical condition p=0.07. *5–19 years*: less likely to swim > 1 min cases 42% vs controls 16% p=0.01† Cases more likely to be non-white, low income or have seizure disorder p<0.01. Limited by small sample numbers. Incentive payment.

*Statistically significant improvement.
†No improvement not statistically significant/no change.
‡Improvement but not statistically significant.
PFD, personal flotation devices.

Table 3 Effectiveness of drowning interventions using pool fencing (included studies)

Interventions				
Study characteristics (quality)	**Intervention description**	**Key elements**	**Measures**	**Results**
Morgenstern et al[20] *Pool deaths and the effect of local ordinances*				
Retrospective cohort and case–control Evidence level: III-2 Pool deaths matched to pools with no deaths <10 years USA	Incidence of drowning deaths in residential swimming pools (N=146) matched to pools with no drowning (1:5) between 1 January 1990 and 31 December 1995. Cases stratified to age and location for comparison that included housing and property characteristics.	Whether a pool fencing ordinance was in effect when pool was built and the effect on pool drowning fatalities.	Outcome: incidence of fatal pool drowning. Exposure: presence or absence of pool fencing ordinance when pool built or altered. Other: Demographic and other potential confounders also investigated.	Pool fencing ordinances and drowning not significantly associated RR=1.27 (95% CI 0.72 to 2.25)*. Incidence rate 1.77/100 000/year 1–9 years for fatal drowning. 1–4 years 3.61/100 000 81% of all drowning occurred in pools in areas regulated by pool fencing ordinances. Possible explanations: ineffective building codes for pool isolation, insufficient ordinance enforcement and/or inadequate operation or maintenance of fencing equipment by pool owners. Ordinance did not specify four-sided fencing. Other risk factors: Positive associations were observed between drowning and: Age 1–4 years; male; ethnicity (Hispanic/Latino and white non-Hispanic); summer season; high and medium pool density; low parental education; high family income (none significant in adjusted analyses).
Pitt and Balanda [21] *Domestic pool drowning (fatal and non-fatal) and the effect of pool fencing*				
Case–control population-based Evidence level: III-2 Domestic pool fatal and non- fatal drowning and pool fencing 0–13 years Australia	Risk of drowning in fenced or unfenced pool calculated through ratio of immersions to fenced and unfenced pools. Immersion cases (n=139) presenting to ED July 1984–June 1989. Controls (n=204) randomly selected from Home Safety Survey conducted in July 1989. Stratified by existence of pool fencing. Drowning death certificates accessed for 1984–1989.	Pool fencing defined as four-sided vs unfenced/three-sided. Survey of pool fencing conducted by interviewers on-site. Telephone interview for retrospective pool/patient information.	Outcome: fatal and non-fatal drowning Fatal and non-fatal drowning where unintended pool access was gained. Exposure: fenced vs unfenced pools. Pool type: above ground, in ground and spas. Fencing configuration: 4-sided vs unfenced, which includes three-sided fencing. Incidence rates calculated for drowning in different pool types.	Compared to fenced domestic pools: RR=3.76 all unfenced domestic pools (95% CI 2.14 to 6.62)† RR=4.10 unfenced in-ground pools (95% CI 2.11 to 8.00)† RR=4.30 unfenced above-ground pools (95% CI 1.09 to 16.97† Incidence rates: Overall 0–13 years fatal and non-fatal 3.3/100 000 Non-fatal 0–13 years 15.5/100 000. Non-fatal 1–3 years 64.9/100 000. Other descriptive risk factors 71% child and family unfamiliar with hazard; 28% of children granted access. *0–13 years*: 72% of drowning locations in domestic pools; 72% of all pool drowning cases had unintended pool access *1–3 years*: 89% of pool drowning;

*No association and not statistically significant.
†Statistically significant association.
ED, emergency department.

vests (personal flotation devices (PFD)).[17] Even though a specific prevention intervention and age group were targeted in this study, the programme was delivered to the entire population of the county.

Swimming and water safety lessons

Swimming and water safety lessons (table 2) have been proposed as possible prevention strategies for drowning as they provide children with the required skills and knowledge to keep themselves safe or remove themselves from danger. The included studies[16 18] examined the effect of swimming and water safety lessons.

The effects of formal or informal swimming lessons on drowning risk were examined in a case–control study.[18] The results of this study indicate that prevention skills can be learned in young children aged 1–4 years, through formal instruction for swimming lessons, but the apparent protective effects did not extend to infants or older children aged 5–19 years. The second study, by Asher *et al*[16], was a study where children were randomly assigned to either 8 or 12 weeks of swimming lessons, but had no control group. This study also provides evidence that swimming lessons can improve swimming ability in young children (aged 2–3 years). However, with no control group in this study, it is possible that the effect can be explained by water familiarity rather than improved skill level. Little detail was provided regarding the composition and duration of swimming lessons in the case–control study, so it is not possible to determine whether the two studies were comparable.

A further limitation of the study by Asher *et al*[16] was that no children younger than 2 years took part, yet these children are at high risk for drowning and are often targeted for such aquatic programmes.[24] Other limitations such as a lack of a control group, volunteer bias (towards higher socioeconomic strata and incentive payments), simulated risk as a proxy for drowning (ethically this is difficult to validate), a relatively small sample size (109 participants) and short duration (12 weeks) with no long-term follow-up for sustained skills or negative effects (such as over confidence) mean that results should be cautiously considered. Benefits of training must be viewed in the context of age of the child, particularly when pool deck behaviour (and the risk of falling in) was not affected as positively. Swimming and water safety skills were acquired more easily than behaviour change; however, reliability or sustainability was not tested.

The study by Brenner *et al*[18] should also be considered in the context of its limitations, including small sample size, a small proportion of children 1–4 years who had participated in swimming lessons, volunteer bias, potential measurement bias because of difficulty in contacting next of kin for cases and quality of information when obtained. However, the study did attempt to control for known confounders such as age, race, education, income and medical condition.

Pool fencing

In HIC, pool fencing (table 3) is proposed as an intervention to prevent children from drowning in home swimming pools by restricting access to the pool.

Two case–control studies (one US and one Australian)[20 21] examined the effect of pool fencing on drowning. The studies had conflicting results due to differing outcome measures. Pitt and Balanda[21] measured the role that fencing plays in preventing drowning, while Morgenstern *et al*[20] measured the effect of pool fencing ordinances, rather than fencing itself. The protective effect of pool fencing has previously been shown[25] to only protect young children aged less than 3 years from gaining unintended access. However, both these studies included children who were older and who were presumably able to gain access to a pool even if a fence were in place. Both of these studies found that toddlers aged 1–4 years were most commonly involved in pool drowning deaths. In the USA, the pool death rate for children aged 1–4 years was 3.6 per 100 000; and in the Australian study for children aged 1–3 years, it was 4.8 per 100 000. Morgenstern accessed coroner's data to measure drowning deaths, while Pitt and colleagues accessed data for fatal and non-fatal drowning events to describe the involvement of access to domestic pools in drowning in Brisbane City South.

In the Brisbane study, cases were fatal and non-fatal drowning incidents in the City of Brisbane presenting to the ED of one of the children's hospitals (where 'immersion' presentations were commonly admitted for observation). Deaths were validated through Registry records. Interviews were conducted with parents to ascertain pool fencing details. Controls were recruited from a Home Safety Survey conducted by the Australian Bureau of Statistics (ABS), where on-site inspections of 204 randomly selected homes with pools provided details of pool fencing. The sample population for cases and controls differed somewhat, as the cases were from Brisbane South and the controls from greater Brisbane City, which included Brisbane North. An assumption was made that fencing would be similar on both sides of the city. In this study, four-sided pool fences were more effective (RR 3.76 95% CI 2.14 to 6.62) than unfenced or three-sided fenced pools. The authors acknowledged that the effectiveness of four-sided fencing is limited by whether a functioning self-closing gate is fitted, as all children with unintended access did so through an open gate or house door.

Conversely, Morgenstern *et al*[20] used a combination of retrospective cohort study and case–control design to measure the effect of pool fencing ordinances on childhood drowning deaths using the same population and the same timeframe in Los Angeles County. Coroner's data were accessed to identify cases and estimate a fatal drowning rate in children <10 years. Cases were matched to five control pools (identified by a private firm of county records) where drowning did not occur. The measure of exposure for the case–control analyses was whether a pool fencing ordinance was in effect where the pool was located rather than pool fencing itself. In this study, overall drowning rates were not lower in pools regulated by fencing ordinances (OR=1.27; 95% CI 0.72 to 2.25). The passing of legislation had not lowered drowning risk on its own. The confounding effects of community campaigns and household characteristics were not ruled out. The study did compensate for the non-retrospective nature of some ordinances by restricting the control sample selection to pools built before 1996; however, the study did not document the presence or configuration of the fencing in existence to test the level of enforcement. Isolation fencing (four-sided) was also not a requirement under the ordinances, which is a factor that the Brisbane study has highlighted as important.

Quality assessment

Methodological limitations of the included studies are presented in the 'Results' section. Overall, there was a lack of consistency in the ages targeted for study, which makes comparative analysis difficult. For intervention studies, measures of effectiveness are challenging as none of the included studies reported results based on objective morbidity or mortality reduction figures and none reported significant changes, primarily because numbers were

too small to definitively assess between-group differences. While objective data were included in four studies, most of the reported analyses relied on self-reported knowledge, attitudes and behaviour. Because fatal drowning incidents are infrequent events, including non-fatal data provides greater numbers to make statistical analyses and evaluations more reliable. Such data can facilitate evaluation of population-level interventions by providing an objective measure of drowning. Intervention studies were limited by short follow-up time preventing capacity for studies to demonstrate sustained effects of the intervention as well as measurement bias associated with self-reported data, recall bias and lack of consideration of relevant confounders. Importantly, studies on interventions and risk factors did not use consistent measures of exposure data. When exploring the effectiveness of pool fencing, exposure information is essential—such as accurate numbers of pools, numbers of dwellings, presence of children in dwelling and the presence of pool fencing, configuration and status.

A consistent definition of drowning has been formalised along with recommended guidelines for uniform reporting of data from drowning[26 27] The terms fatal and non-fatal drowning are used here in preference to immersion, submersion, drowning and near drowning. It is important that future studies use these guidelines for clarity and comparability in scientific communications, particularly when discussing fatal and non-fatal incidents. Consistent use of other terminology such as 'swimming ability' and 'learning to swim' highlights the need for standardisation of terminology. We were unable to determine whether included studies that investigated swimming lessons as an intervention employed the same definition, making comparison difficult.

Excluded literature

Twenty-eight studies excluded from this systematic review did not fulfil the selection criteria, principally due to study design and/or other methodological limitations. There were a wide range of other strategies described that proposed to reduce drowning deaths. Interpretation of their findings must be undertaken with caution because of methodological limitations. There is little or no evidence provided that any are effective in relation to reduction in drowning deaths and reinforces the need for well-designed, controlled studies where interventions are implemented. Risk factors identified in these articles are also reported (box 1).

DISCUSSION

Drowning continues to be a significant public health challenge globally. While there have been a large number of published studies exploring drowning and possible prevention solutions, there is a dearth of large population-based studies that produce high levels of evidence. This systematic review analysed studies of drowning over a 30-year period; however, it was not until 2005 and that a universal definition of drowning was developed that has limited our ability to compare studies.[27]

The seven studies that met our inclusion criteria explored the drowning prevention interventions associated with education, swimming ability and pool fencing. What is clear is that child drowning is a significant issue, especially for children aged less than 5 years. There is very little information about the older adolescents aged 15–19 years. Each of the intervention strategies has some impact on reducing drowning deaths with the strongest evidence coming from pool fencing. This is consistent with Haddon's Hierarchy of Control, where restricting the child's access to water is higher in the hierarchy.[56 57] However, no one strategy is independently effective in preventing all drowning.

Interventions

Education

Few studies reported results based on morbidity or mortality reduction figures. Most relied on self-report evaluations rather than independent observations of behaviour change[17 19 22] potentially creating bias. The short time period between the intervention and postintervention evaluations may have contributed to high recall scores and has limited any capacity to demonstrate whether the effects were sustained for any length of time. It is also possible that control group participants were exposed to drowning prevention information from other sources in the community or media, which could have improved their knowledge as much as the intervention groups. One study did not include a control group, limiting ability to definitively attribute any observed changes to the intervention.

While none of the studies on education interventions was conclusive, each of the three studies provided some evidence that education may have some effect. Success was attributed to education interventions that were (a) specific in their content and targeted in their reach, (b) delivered in settings appropriate to the target age groups, (c) contained information tailored to the specific injury type and (d) safety devices were provided. Increased overall safety behaviours were attributed to the provision of safety devices, but their use for drowning prevention was not easy to measure, with non-slip bath decals and PFD incentive/loan schemes inconclusive. Recent meta-analyses[58] support education as being effective, along with providing or discounting sales, on safety devices. In contrast to the successes stated above, interventions delivered in the home rather than clinical settings reduced injury, and meta-regression indicated that interventions may not necessarily need to be tailored for specific groups based on some socio-demographic factors.

Education interventions need to be considered in the context of feasibility of delivery in the setting. Commonly cited barriers to prevention in the primary care setting are time pressures on staff that prevent proper counselling; too much information being covered at one time on various injuries or that a parent may be consumed with the more pressing or acute problems associated with their visit to the primary care setting.[22] Studies such as these and those delivered in the home are labour intensive in their delivery and usually require trained staff to counsel or educate on an individual level. Smaller populations, longer timeframes and information on intensity of delivery could allow for greater understanding of effectiveness. Settings-based analyses or interventions that are appropriate to readiness (or stage) of change[11 56] may help to better define the audiences and appropriate education strategies for intervention.

Swimming lessons and water safety

These studies provided some evidence to show that swimming lessons improve swimming ability in children aged 2–4 years and most importantly do not place a child at increased risk of drowning. However, there is no evidence as to whether this is a sustained or enduring skill nor whether it is transferable to various aquatic settings. It is also not a viable intervention for children under 2 years old as swimming lessons in this age group is unproven.[59] Children in older age groups who can swim still drown, so while swimming ability can improve, this is an adjunct preventative intervention not a solution on its own. This area of research requires methodology that builds on that used in the studies used in this review, including measurable criteria for what a formal swimming lesson entails, participation, retention of skills and importantly those 0–2 years old who

Box 1 Interventions and risk factors discussed in studies that did not meet eligibility criteria

Interventions
- Pool fences (including legislation/proper installation/inspection)[28–40]
- Water safety education[33 35–37 39 41–48]
- Increased supervision[30 33 37 39 44 49]
- Swimming lessons for children[33 39 44 46 49 50]
- Cardiopulmonary resuscitation knowledge[28 30 33]
- Alcohol (reducing drinking age/limiting use)[51 52]
- Wearing life vest and lifeguard presence[36 53–55]

Risk factors
- Age group 0–4 years[28 32 34 37 43 49 55]
- Young age up to 10 years[30 44 50]
- Masculine gender[39 41 50]
- Ethnicity (indigenous/immigrants/tourists)[36 44 50]
- Lack of supervision[36 46 49]
- Pools[34 35 37 39 55]
- Pool fencing (lack of or inadequate)[35 38]
- Bathtubs[37]
- Dams/ponds/rivers[32 39 49]
- Sea/coast[50]
- Poor swimming ability[49]
- Summer season[32 37]
- Alcohol and adolescents[28 41 52]

undertake water familiarisation classes. Acquiring water safety skills is achievable by younger children; however, the average time taken to achieve these skills from the start of the formal lessons increases with the decreasing age of the child.[60]

Pool fencing

Pool fencing can restrict children's access to water; however, the fencing needs to be well maintained with an operating self-closing, self-latching gate; and when children are in the pool space, supervision and aquatic skills are required. Organisational change (at government level) is necessary to improve safety behaviour beyond the mere passing of safety laws. The success of the legislation is dependent upon it containing evidence-based building codes and standards,[20] four-sided isolation fencing that limits access from the house,[21] inspection regimes that ensure maintenance of fencing and dynamic gates[21] and retrospective application so that all types of pools (no matter when constructed) are captured within the legislation.[20]

There is less evidence to support the use of pool fencing for preventing non-fatal drowning incidents. Only one study[21] included non-fatal drowning cases in analyses. Better quality studies are required to demonstrate the efficacy of pool fencing to reduce non-fatal drowning.

Not surprisingly, the density of swimming pools has been found to contribute to the rate of drowning[20] as it is a proxy for exposure, and children are also more likely to drown in their own pool. It is important to note that in rare studies where detail is available[21] there were no cases where a child was known to have scaled a fence to gain access to a pool.[11 21] It is inevitable that as more pools use four-sided fencing and have secure gates, the phenomenon of children climbing fences or actively gaining access will occur and present challenges for prevention. Work conducted in the late 1970s by Nixon[25] found that 80% of children aged 2 years (the modal age for drowning) could not climb a 60 cm fence. However, 20% of 3 year olds could climb a 1.2 m barrier, which is the recommended minimum height of a pool fence. Regardless of the height, the time required to cross the barrier decreased as the child's age increased, with a mean range of 16–9 s for children aged 4–9 years to cross a 1.2 m barrier. This emphasises that pool fencing for this age group is a time-delaying mechanism and therefore cannot replace active supervision.

The effect of legislation on injury rates can only be measured by up-to-date and reliable surveillance, which includes pool numbers and the presence and status of fencing. Data collected should include the sequence of events leading to drowning, pool density, exposure and fencing configuration in place.

Methodological limitations that limited validity and reliability of the included studies' findings were discussed in the 'Results' section. Interpretation of findings must be used with caution. Meta-analyses were not appropriate due to heterogeneity in study designs, interventions and measures. The validity of conclusions from any systematic review depends on the evidence level of the included studies. In this case, many of the studies reviewed were limited in their ability to draw conclusions due to differences in methodology and definitions. The paucity of studies may be due to our search strategy, which excluded grey literature and papers not published in English. It is also possible that the included studies were not representative of all studies that have been conducted on this topic because of publication bias. Five of the seven studies were conducted more than 10 years ago, and so their currency is questionable.

Clearly, methodologically sound studies on evaluation of interventions are much needed in this area. Studies should employ appropriate study design, comparable control groups, use objective and reliable measures (including morbidity and mortality data where appropriate), sufficient sample size, be of sufficient time period, use consistent definitions and include an accurate measure of exposure. Such methodological improvements will allow definitive intervention evaluation and identification of risk factors. This will inform prevention strategies, and ultimately, reduce drowning in children.

Future interventions and strategies will predictably be affected by funding and need; however, expertise and collaboration between low and/or middle income countries (LMIC) and HIC is encouraged to employ rigorous methodology to achieve repeatable outcomes and high levels of evidence.

CONCLUSION

Few studies employ rigorous methods and high levels of evidence to assess the impact of interventions designed to reduce drowning. Seven studies met the inclusion criteria and demonstrate that interventions such as education, pool fencing and swimming and water safety are possible effective strategies to prevent children from drowning, particularly those 2–4 years of age. There were a number of promising studies identified that did not meet the inclusion criteria. Future research could validate the potential prevention strategies around many of these, such as cardiopulmonary resuscitation training and wearing of PFDs. Drowning is a significant public health challenge globally, and there is a need for rigorous, well-designed studies that use consistent terminology to demonstrate effective prevention solutions.

What is already known on the subject

The first four years of life are the most vulnerable for drowning; the risk increases with increasing mobility of toddlers.

What this study adds

- This review reports on interventions for drowning prevention across the age spectrum of children and adolescents up to the age of 19.
- Evidence-based strategies for reducing drowning in high-income countries are pool fencing, swimming and water safety lessons, and targeted education campaigns.

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REFERENCES

1 Peden M, Oyegbite K, Ozanne-Smith J, *et al*, eds. World report on child injury prevention. Geneva: WHO and UNICEF, 2008.
2 WHO. *Facts about injuries—drowning*. Geneva: World Health Organization, 2004.
3 Pearn J, Nixon J. An analysis of the causes of freshwater immersion accidents involving children. *Accid Anal Prev* 1979;11:173–8.
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 Brenner RA, Saluja G, Smith GS. Swimming lessons, swimming ability, and the risk of drowning. *Inj Control Saf Promot* 2003;10:211–16.
6 Quan L, Cummings P. Characteristics of drowning by different age groups. *Inj Prev* 2003;9:163–8.
7 Rivara FP, Grossman DC, Cummings P. Injury prevention. Second of two parts. *N Engl J Med* 1997;337:613–18.
8 Pearn J, Nixon J. Bathtub immersion accidents involving children. *Med J Aust* 1977;1:211–13.
9 Brenner RA, Trumble AC, Smith GS, *et al*. Where children drown, United States, 1995. *Pediatrics* 2001;108:85–9.
10 American Academy of Pediatrics. Policy Statement--Prevention of Drowning. *Pediatrics* 2010;126:178–85.
11 McClure RJ, Davis E, Yorkston E, *et al*. Special issues in injury prevention research: developing the science of program implementation. *Injury* 2010;41(Suppl 1): S16–19.
12 Bhalla K, Harrison J, Abraham J, *et al*. Data sources for improving estimates of the global burden of injuries: call for contributors. *PLoS Med* 2009;6:e1000001.
13 Global Burden of Disease Injury Expert Group. GBD Injury Expert Group. http://sites.google.com/site/gbdinjuryexpertgroup/Home/literature-review
14 National Health and Medical Research Council. How to review the evidence: systematic identification and review of the scientific literature. 1999. http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/cp65.pdf (accessed Feb 2014).
15 NHMRC, National Health and Medical Research Council. NHMRC additional levels of evidence and grades for recommendations for developers of guidelines. 2009. https://www.nhmrc.gov.au/_files_nhmrc/file/guidelines/developers/nhmrc_levels_grades_evidence_120423.pdf (accessed Feb 2014).
16 Asher KN, Rivara FP, Felix D, *et al*. Water safety training as a potential means of reducing risk of young children's drowning. *Inj Prev* 1995;1:228–33.
17 Bennett E, Cummings P, Quan L, *et al*. Evaluation of a drowning prevention campaign in King County, Washington. *Inj Prev* 1999;5:109–13.
18 Brenner RA, Taneja GS, Haynie DL, *et al*. Association between swimming lessons and drowning in childhood: a case-control study. *Arch Pediatr Adolesc Med* 2009;163:203–10.
19 Gresham LS, Zirkle DL, Tolchin S, *et al*. Partnering for injury prevention: evaluation of a curriculum-based intervention program among elementary school children. *J Pediatr Nurs* 2001;16:79–87.
20 Morgenstern H, Bingham T, Reza A. Effects of pool-fencing ordinances and other factors on childhood drowning in Los Angeles County, 1990–1995. *Am J Public Health* 2000;90:595–601.
21 Pitt W, Balanda K. Childhood drowning and near-drowning in Brisbane: the contribution of domestic pools. *Med J Aust* 1991;154:661–5.
22 Posner J, Hawkins L, Garcia-Espana F, *et al*. A randomized, clinical trial of a home safety intervention based in an emergency department setting. *Pediatrics* 2004;113:1603–8.
23 Wikipedia. http://en.wikipedia.org/wiki/Education_in_the_United_States Wikipedia —Education in the United States. 2012.
24 American Academy of Pediatrics Committee on Injury and Poison Prevention. Swimming programs for infants and toddlers. Committee on Sports Medicine and Fitness and Committee on Injury and Poison Prevention. *Pediatrics* 2000;105(4 Pt 1):868–70.
25 Nixon J, Pearn JH, Petrie GM. Childproof safety barriers. *Aust Paediatr J* 1979;15:260–2.
26 Idris AH, Berg RA, Bierens J, *et al*. Recommended guidelines for uniform reporting of data from drowning: the "Utstein style". *Circulation* 2003;108:2565–74.
27 van Beeck EF, Branche CM, Szpilman 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 Centers for Disease Control. Nonfatal and fatal drownings in recreational water settings—United States, 2001–2002. *MMWR Morb Mortal Wkly Rep* 2004;53:447–52.
29 Fisher KJ, Balanda KP. Caregiver factors and pool fencing: an exploratory analysis. *Inj Prev* 1997;3:257–61.
30 Gardiner SD, Smeeton WMI, Koelmeyer TD. Accidental drownings in Auckland children. *N Z Med J* 1985;98:579–82.
31 Hassall IB. Thirty-six consecutive under 5 year old domestic swimming pool drownings. *Aust Paediatr J* 1989;25:143–6.
32 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.
33 Liller KD, Kent EB, Arcari C, *et al*. Risk factors for drowning and near-drowning among children in Hillsborough County, Florida. *Public Health Rep* 1993;108:346–53.
34 O'Carroll PW, Alkon E, Weiss B. Drowning mortality in Los Angeles County, 1976 to 1984. *JAMA* 1988;260:380–3.
35 Pearn JH, Nixon JW, Franklin RC, *et al*. Safety legislation, public health policy and drowning prevention. *Int J Inj Contr Saf Promot* 2008;15:122–23.
36 Quan L, Pilkey D, Gomez A, *et al*. Analysis of paediatric drowning deaths in Washington State using the child death review (CDR) for surveillance: what CDR does and does not tell us about lethal drowning injury. *Inj Prev* 2011;17(Suppl 1):i28–33.
37 Ross FI, Elliott EJ, Lam LT, *et al*. Children under 5 years presenting to paediatricians with near-drowning. *J Paediatr Child Health* 2003;39:446–50.
38 Stevenson MR, Rimajova M, Edgecombe D, *et al*. Childhood drowning: barriers surrounding private swimming pools. *Pediatrics* 2003;111:E115–19.
39 Tan RMK. The epidemiology and prevention of drowning in Singapore. [see comment]. *Singapore Med J* 2004;45:324–9.
40 Zhang P, Chen RH, Denh JY, *et al*. Evaluation on intervening efficacy of health education on accidental suffocation and drowning of children aged 0–4 in countryside. *Zhonghua Er Ke Za Zhi* 2003;41:497–500.
41 Cummings P, Quan L. Trends in unintentional drowning: role of alcohol and medical care. *JAMA* 1999;281:2198–202.
42 Davis S, Ledman J, Kilgore J. Drownings of children and youth in a desert state. *West J Med* 1985;143:196–201.
43 Ellis AA, Trent RB. Swimming pool drownings and near-drownings among California preschoolers. *Public Health Rep* 1997;112:73–7.
44 Garssen MJ, Hoogenboezem J, Bierens JJLM. Reduction of the drowning risk for young children, but increased risk for children of recently immigrated non-Westerners. *Ned Tijdschr Geneeskd* 2008;152:1216–20.
45 Gofin R, De Leon D, Knishkowy B, *et al*. Injury prevention program in primary care: process evaluation and surveillance. *Inj Prev* 1995;1:35–9.
46 Moran K, Stanley T. Toddler drowning prevention: teaching parents about water safety in conjunction with their child's in-water lessons. *Int J Inj Contr Saf Promot* 2006;13:254–6.
47 Petronis KA, Welch JC, Pruitt CW. Independent risk factors for beach-related injuries in children. *Clin Pediatr (Phila)* 2009;48:534–38.
48 Quan L, Bennett E, Cummings P, *et al*. Do parents value drowning prevention information at discharge from the emergency department? *Ann Emerg Med* 2001;37:382–5.
49 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.

50 Thelot B, Marant C, Bonaldi C, *et al*. The heavy toll of accidental drowning: 401 deaths in France during the summer 2006. *J de Pediatrie et de Puericulture* 2008;21:239–43.
51 Howland J, Birckmayer J, Hemenway D, *et al*. Did changes in minimum age drinking laws affect adolescent drowning (1970–90)? *Inj Prev* 1998;4:288–91.
52 Driscoll TR, Harrison JE, Steenkamp M. Alcohol and drowning in Australia. *Inj Control Saf Promot* 2004;11:175–81.
53 Quan L, Bennett E, Cummings P, *et al*. Are life vests worn? A multiregional observational study of personal flotation device use in small boats. *Inj Prev* 1998;4:203–5.
54 Schwebel DC, Lindsay S, Simpson J. Brief report: a brief intervention to improve lifeguard surveillance at a public swimming pool. *J Pediatr Psychol* 2007;32:862–8.
55 Steensberg J. Epidemiology of accidental drowning in Denmark 1989–1993. *Accid Anal Prev* 1998;30:755–62.
56 Franklin RC, Scarr JP. *Drowning – Prevention, Rescue, Treatment*, 2nd ed. Germany: Springer Oct 2014.
57 Haddon W Jr. Why the issue is loss reduction rather than only crash prevention. *Md State Med J* 1970;19:55–60.
58 Kendrick D, Coupland C, Mulvaney C, *et al*. Home safety education and provision of safety equipment for injury prevention. *Cochrane Database Syst Rev* 2007;(1):CD005014.
59 American Academy of Pediatrics. Technical Report—Prevention of Drowning. *Pediatrics* 2010;126:e253–e62.
60 Parker HE, Blanksby BA. Starting age and aquatic skill learning in young children: mastery of prerequisite water confidence and basic aquatic locomotion skills. *Aust J Sci Med Sport* 1997;29:83–7.

Interventions associated with drowning prevention in children and adolescents: systematic literature review

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