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Review

Aquatic Competencies and Drowning Prevention in Children 2–4 Years: A Systematic Review

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Abstract: Aquatic competencies have been proposed as a prevention strategy for children aged 2–4 years who are over-represented in drowning statistics. For this recommendation to be made, exploration of the connection between aquatic competencies and drowning is required. This review critically analyzed studies exploring aquatic competencies and their effect on drowning and/or injury severity in children 2–4 years. English language peer-reviewed literature up to 31 July 2019 was searched and the PRISMA process utilized. Data were extracted from twelve studies that fulfilled the inclusion criteria. Findings from this study included that aquatic competencies were not found to increase risk of drowning and demonstrated children aged 2–4 years are capable of developing age-appropriate aquatic competencies. Age-appropriate aquatic competencies extracted were propulsion/locomotion, flotation/buoyancy, water familiarization, submersion and water exits. The acquisition of these competencies holds benefit for the prevention of drowning. No evidence was found relating to injury severity. There was limited exploration of the relationship between aquatic competencies attainment and age-related developmental readiness. The review highlights the need for consistent measures of exposure, clarity around skills acquisition, better age-specific data (2 years vs. 3 years vs. 4 years), studies with larger sample sizes, further exploration of the dose–response relationship and consistent skill level testing across age groups. Further investigation is required to establish the efficacy of aquatic competencies as a drowning prevention intervention, as well as exploring the relationship between aquatic competencies and age-related developmental readiness. In conclusion, early evidence suggests aquatic competencies can help to reduce drowning.

Keywords: drowning; water safety; developmental readiness; aquatic competency; swimming skill; prevention; age-appropriate; child; neurodevelopment; learn to swim; risk

1. Introduction

Globally, drowning is the leading cause of unintentional injury death among children [1,2] and, across the life span, claimed 295,000 lives in 2017 [3]. Drowning is among the ten leading causes of death in children in countries of all geographic and demographic compositions [4–6], with children 0–4 years disproportionately at risk both in terms of unintentional drowning deaths and hospitalized non-fatal drownings [2,3].

Drowning is preventable provided people have and apply appropriate knowledge, skills and attitudes [1]. Prevention requires a multifaceted approach focused on context-specific risk factors, targeted age groups and setting appropriateness [1]. Four major strategies have been proposed for preventing child drowning: supervision, restricting access, improving aquatic competencies

and improving cardiopulmonary resuscitation (CPR). These actions link to the World Health Organization's (WHO) 10 point drowning prevention strategy (six interventions and four "cross-cutting" implementation strategies) and are developed on the best evidence available [7]. The actions are designed to help practitioners approach drowning prevention in a strategic and evidence-informed manner, utilizing multi-sectoral partnerships to harness public awareness and engagement [7].

As drowning disproportionately impacts young children, effective prevention stratagems for this age group are needed [8]. In high income countries, children aged up to 1 year most commonly drown in bathtubs, with absence of supervision the key contributor [9–17]. As children become progressively mobile, with low levels of risk perception at around 2 to 4 years of age, swimming pools in high income contexts and other water bodies close to home associated with water storage and the activities of everyday life in low and middle income contexts pose risk, necessitating a wider range of prevention strategies. These include restricting access to water, learning aquatic competencies and appropriate supervision [18]. Restricting access, especially to swimming pools, has been effective in reducing drowning [19]. However, one of the challenges in drowning prevention is protecting those children who evade the barrier or for water bodies where it is challenging to restrict access such as lakes, rivers and oceans. For such situations aquatic competencies have been proposed to provide children with skills and knowledge to keep themselves safe or remove themselves from danger [12,18,20]. However, the relationship between the provision of such skills through swimming lessons, the acquisition of skills and the prevention measures they provide in the given age group is unclear.

The American Academy of Pediatrics (AAP) has taken various stances on swimming lessons for infants and toddlers over past decades since the inception of its Drowning Prevention Policy Statement in 1985. In the current AAP policy it cites evidence that many children older than one year will benefit from swim lessons [18]. The policy, however, only makes reference to one supporting study which has its own limitations [18]. This policy position is formulated around the belief that children under the age of one year cannot voluntarily hold their breath for significant amounts of time [21]. The AAP continues to state " … adequate supervision described as close, constant, and attentive supervision, of young children in or around any water is a preventative strategy" [21] p. 4, advice repeated globally by water safety bodies. The policy states that parents may be able to teach their baby or toddler to love water, but children always need an adult present at all times to prevent drowning [18].

Toddler and preschool formal swim instruction introduce aquatic competencies and water familiarization to both children and parents. However, a continuing problem arising from the various AAP policies over time is defining what constitutes a formal swimming lesson, how water familiarization compares and how to reinforce the need for supervision. It has been argued that aquatic skills gained in the formative years of a child's lifespan are essential for safe aquatic participation throughout life and underpin drowning prevention strategies [22–24]. The benefit of such competencies, however, are not well understood, as there has been limited exploration of the level of skill acquisition in terms of child neurodevelopmental readiness. While attention has been given to what constitutes a fundamental movement on land [25], less attention has been directed towards which movements may be fundamental in aquatic environments and for what purpose (developmental skills/drowning prevention) [22]. There is a move to consider swimming competencies as fundamental movements [22–24], as it has been proposed that global trends in drowning and water-related hospitalization statistics indicate the lack of such skills [22]. However, the question is raised, what water competencies should children learn and at what age are children neurodevelopmentally ready for such skill acquisition?

Neurodevelopmental readiness of children for participation in aquatic competencies programs depends on " … a complex interplay of multiple factors (including) individual factors (level of development, past experiences) and the environmental factors (opportunities, peer and adult attitudes) … " [26] p. 170. Neurodevelopment is often described in terms of specific domains or streams which " … progress concurrently and interdependently … " [26] p. 167. A child's level of participation " … should be guided by individual physical, neuromotor, cognitive, perceptual-motor, and psychological maturation … " (171) [26]. Understanding a " … child's neurodevelopmental level helps adults provide optimal guidance … " [26]

p. 171 for children to successfully participate in activities in an aquatic environment. The literature also presents a stance that "critical periods" determine when a sporting skill (such as an aquatic competency) could ideally be acquired [27–32]. It is important to note that " . . . not all children acquire the skills in the same period due to the impact of environmental factors, and varying rates of growth and developmental progression . . . " [26] p. 167.

Children who have participated in swimming lessons from a young age have been found to demonstrate more advanced cognitive and physical abilities than children who have not [33–35]. A study exploring the effects of baby swimming displayed an increase in abilities associated with prehension and balance [36]. The earliest and/or optimal age(s) at which aquatic competencies should be introduced in a formal manner has been a continually contentious issue in the aquatic and medical fields for over four decades [35].

Recognizing the importance of multiple drowning prevention strategies in 2–4-year olds [7,20], the question "is the acquisition of some form of aquatic competency beneficial?" is raised. This systematic review aims to identify and critically analyze studies of aquatic competencies and their bidirectional effect on drowning events in children 2–4 years of age or the injury severity incurred by such incidents by addressing the following research questions:

1. What effect do aquatic competencies have on drowning incidents in children 2–4 years of age?
2. What effect do aquatic competencies have on the injury severity incurred by such incidents among children 2–4 years of age?
3. What are considered key aquatic competencies, for children aged 2–4 years, in relation to drowning prevention and what evidence is there supporting this?
4. Is there evidence to support children in the given age group being able to acquire these competencies?

2. Methodology

This review followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [37–39]. Following on from Wallis et al.'s systematic review of drowning interventions for children [20], this study focuses on the specific intervention of water competencies for 2–4 year olds.

The PRISMA statement was used to identify, screen, determine eligibility and include studies for analysis from search results [40]. (Figure 1) Literature published in English language between 1930 and 31 July 2019 was searched using Medline, PubMed, Embase, Scopus, PsychInfo, SportDiscus, and the Cochrane Central Register of Controlled Trials. Initial search terms included "drown" and "human" and "competency" and "skill" and "intervention" and "swim". This was deliberately broad and no qualification of methodology or publication type was applied to capture all relevant articles. Boolean search strings are described in the Supplementary Materials attached (Table S1).

A manual search was completed from the references obtained for data extraction. Google Scholar was used in this process to identify papers which had referenced the originally obtained articles, and the reference lists of articles were examined for potential inclusions. Only peer-reviewed literature was considered for data extraction. Two reviewers used the criteria to identify potentially eligible articles (DT & RF). Titles and abstracts were screened by the primary researcher (DT) and eligible publications identified for data extraction. When the primary researcher (DT) was unsure of inclusion, it was reviewed by the second author (RF). A full list of twelve relevant articles was compiled. The full list was retrieved and reviewed by the second author for inclusion (RF). Publications were assessed according to the inclusion and exclusion criteria (Table 1).

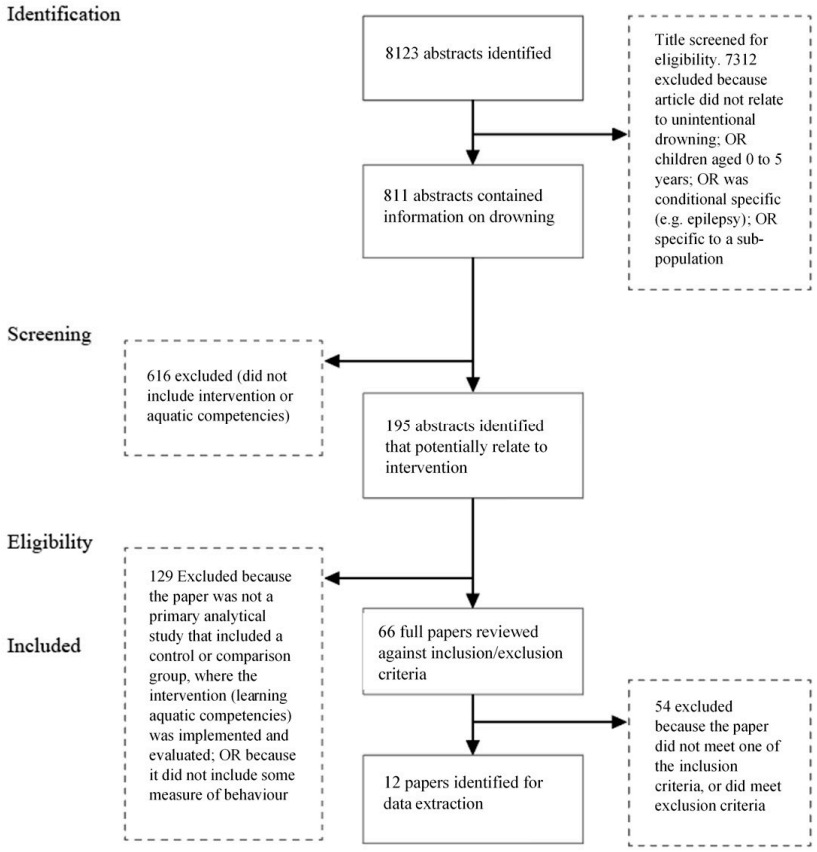

Figure 1. PRISMA Flow Chart outlining procedure of extracting articles for inclusion.

Table 1. Inclusion and exclusion criteria.

• Data from primary analytical studies that include a control or comparison group, where competency (intervention/prevention measure) was implemented and evaluated
• Some measure of behavior was included (did not need to be objective).
○ Exclude studies that include only measures of attitudes/knowledge
• Drowning event was unintentional
• Sample comprised of children between 2–4 years of age
○ or a minimum of 75% of sample
○ or age group could be easily extracted from main data set of relevant studies

Articles related to condition-specific drowning events (e.g., epilepsy) were excluded. The decision was made to also exclude publications that related specifically to subpopulations (e.g., fishing incidents, snorkeling, chronic medical conditions, congenital delayed neurodevelopmental disorders, hurricanes and tsunamis). Intentional drowning was also excluded.

The data extraction form used to assess the methodological quality of the articles for the purpose of this review was adapted from the McMaster Qualitative Studies Critical Review Form [41]. Studies were analyzed according to their characteristics, measures, results and study quality. Study quality included assessment of study design, sample (composition and size), measurements and potential biases affecting validity. The level of evidence was also assessed, providing each article with a rank within the research hierarchy [42,43]. The rank provided reflects the potential of each study to adequately answer the set research questions, based on the probability that its design has minimized the impact of bias on the

results. The (Australian) National Health and Medical Research Council level of evidence hierarchy that quantifies evidence into four levels (highest evidence being I—a systematic review of randomized control trials to IV—case series with either post-test or pre-test/post-test outcomes) was utilized [42,43].

2.1. Definition of Key Terms

For the systematic review to have independent standing, it was critical to define both the terms drowning and aquatic competency.

2.1.1. Drowning

The well-utilized definition for drowning was adopted by this study [44–46]. Drowning was defined as "the process of experiencing respiratory impairment from submersion or immersion in liquid" [44] p. 853. Drowning outcomes are classified as either drowning with mortality, drowning with morbidity or drowning without morbidity [44]. All are encompassed by this study.

2.1.2. Aquatic Competency

There is no universally agreed definition for what constitutes aquatic competency [47]; however, it is thought to incorporate two essential aspects—flotation to permit breathing and propulsion to provide mobility [48]. It is often described in terms of ability to swim an arbitrary distance but for this study will encompass a more comprehensive term than swimming ability and is better reflected as a composition of aquatic skills and knowledge associated with aquatic activity [49]. This study agrees with the notion proposed by Brenner and colleagues that swimming ability be promoted as a necessary component of aquatic competence, which is the wider term for all water-based skills but with the understanding that swimming ability alone is not sufficient to prevent drowning [50]. Therefore, this study adopts the more comprehensive notion of aquatic competency to describe a set of survival skills that may prevent drowning.

3. Results

Twelve articles [51–62] were retained for inclusion in this review (Figure 1). These studies are described in Table 2 and Table S2. There were 2376 (range 42–399) participants across the 12 studies. There was one randomized controlled trial (without control group) [58], five case-control (population based) studies [55–57,61,62] and six case series studies (including four retrospective case series) [51–53,57,59,62]. The papers spanned four countries including seven articles from the United States of America (USA) [51,52,55,58,60–62], three from Australia [53,57,59], one from Portugal [54] and one from China [56]. The studies explored an age range of 0 to 19 years. Once the data were abstracted for 2–4 year olds, the most common age group targeted in the studies were the three [51–53,55–61] and four [51–57,59–61] year old cohorts (10 papers respectively). The two-year old cohort was represented by eight papers [53,55–58,60–62] (Table 2). Of the 12 studies, nine examined the acquisition of aquatic competencies [51–54,57–59,61,62] and five examined the effect of acquiring aquatic competencies on drowning prevention among the target age group [53,55,56,58,60].

Table 2. Water competencies as an intervention for drowning prevention (included studies).

Author	Year	Country	Age Explored	Total Number of Participants	Study Design	Level of Evidence [1]
Olaisen et al. [51]	2018	USA	3–14 Years	149	Case Series	IV
Anderson and Rodriguez [52]	2014	USA	3–8 Years	272	Retrospective case series	IV
Bugeja and Franklin [53]	2013	Australia	0–4 Years	80	Retrospective case series	IV
Costa et al. [54]	2012	Portugal	4 Years	98	Case–control population-based	III-2
Brenner et al. [55]	2009	USA	1–19 years	301	Case–control population-based	III-2
Yang et al. [56]	2007	China	1–14 Years	399	Case–control population-based	III-2
Parker and Blanksby [57]	1997	Australia	2–7 Years	264	Retrospective case series	IV

Table 2. *Cont.*

Author	Year	Country	Age Explored	Total Number of Participants	Study Design	Level of Evidence [1]
Asher et al. [58]	1995	USA	24–42 months	109	Randomized trial no control	III-3
Blanksby et al. [59]	1995	Australia	3–9 Years	326	Retrospective case series	IV
Rodgers [60]	1989	USA	0–59 months	140	Case-control population-based	IV
Erbaugh [61]	1986	USA	2.5–5.5 Years	126	Case–control population-based	III-2
McGraw [62]	1939	USA	0–30 months	42	Case Series	IV

[1] III-2 = a comparative study with concurrent controls; III-3 = A comparative study without concurrent controls; IV = Case series with either post-test or pre-test/post-test outcomes.

3.1. Aquatic Competencies and the Reduction of Drowning Events

Aquatic competencies may hold some benefit as an intervention for drowning risk reduction if taught in a formal swimming lesson environment (Table 3). A case-control population study of 140 swimming pool child-drowning incidents by Rodgers revealed a lower relative risk (RR) of drowning was associated with better swimming ability as reported by parents [60]. Yang et al. found drowning incidents among children who had had swimming lessons (6.8%) were less likely than among the control group (12%) [56]; similar findings to Brenner et al. (3% and 26%, respectively) [55]. Yang et al. concluded that swimming lessons might be protective even for younger children, with children not receiving formal swimming lessons a risk factor for drowning (OR: 1.8; 95% CI: 1.1–5.5) [56]. Brenner et al. stated there was an 88% (OR: 0.12; 95% CI: 0.01–0.97) reduction in drowning risk among those with swimming lessons [55]. The wide confidence interval, however, does not allow for a precise estimate of risk reduction.

Table 3. Water competencies as an intervention for reducing drowning risk.

Author	Cohort	Measures	Results
Asher et al. [58]	24–42 months, n = 109	Three skills sets: Out of water safety behavior Swimming ability In-water safety skills Measured were assessed by independent blinded observers (instructors) for both the swimming ability and water safety skills. Parents undertook a self-report survey child development and demographics.	Evidence swimming lessons improve water competencies in children 2–3 years. Deck behavior did not improve $p < 0.03$.[1] Significant improvement was found in water recovery ($p < 0.001$.[2]) Significant improvement could be attributed to water familiarity gained by participants Swimming was recommended as part of a comprehensive approach to water safety. Water safety instruction does not increase risk of drowning
Brenner et al. [55]	1–4 Years, n = 195	Exposure Swimming ability Swimming lesson participation (formal and informal) Self-report survey by parents reporting on child development, household characteristics, medical conditions and psycho-social characteristics. How measure assessed by fatal drowning	Children participated in formal swimming lessons less likely to drown (OR 0.12; 95% CI 0.01–0.97) [3] No significant associations were observed between informal swimming instruction and drowning in age group Limited by small sample numbers. Incentive payment.
Bugeja and Franklin [53]	0–4 Years, n = 80	Outcome fatal drowning. Limited to coroner's death investigation records Water familiarization defined as participation in formal swimming lessons.	Water familiarization evidence was limited as there was a high frequency of unknowns (n = 58, 72.5%). 22 deaths information unavailable, 13 children had some previous water experience, 5 children participated in formal swimming lessons, 9 children no experience with water. Level of caregiver supervision was shown to be greater for children who had participated in swimming lessons.
Rodgers [60]	0–59 Months, n = 140	Child swimming ability by age via two surveys; 1. Children who had experienced a backyard pool drowning 2. Households owning residential swimming pools. Outcome fatal drowning.	While not statistically significant, swimming ability showed a reduction in the risk of an incident, increasing as the child ages.
Yang et al. [56]	1–4 years, n = 192	Attendance at swimming lessons? (Y/N) via a semi structured questionnaire, controls were age- and gender-matched. Child and caregiver behavioral characteristics. Outcome fatal drowning.	A child who did not attend swimming lessons was more likely to drown (OR 1.8; 95% CI 1.1 to 5.5) [2] Significant risk factors: poor health of caregiver (OR 3.1; 95% CI 1.9 to 5.8), not using flotation devices (OR 2.3; 95% CI 1.4 to 4.5) and no proper swimming lessons (OR 1.8; 95% CI 1.1 to 5.5). Swimming lessons may protect children 1–4 years of age.

[1] Statistically significant improvement; [2] No improvement not statistically significant/no change; [3] Improvement but not statistically significant; Y/N = Yes/No.

Asher et al. found children were able to develop the water-safety skills necessary to survive a fall into a home swimming pool [58]. Water recovery (i.e., the ability to recover and stand up in a body of water) showed significant improvement ($p < 0.001$) [58]. Water familiarization findings were limited in Bugeja and Franklin [53]; however, five (6.3%) children who had participated in formal swimming lessons drowned in their study, noting that for 22 (27.5%), swimming lesson participation was unknown [53]. Results identified that children who were known to participate in formal swimming lessons had greater levels of caregiver supervision [53,56,60] (Table 3).

3.2. Aquatic Competencies and the Reduction of Injury Severuty in Drowning Events

No studies which satisfied the inclusion criteria investigated whether aquatic competencies reduce the injury severity sustained in a drowning event among 2–4 year olds. Rodgers [60] attempted to examine and quantify factors affecting the risk of child fatal and non-fatal drowning incidents in residential swimming pools and the impact of swimming lessons. Findings suggest swimming ability may reduce risk of an incident (both fatal and non-fatal); however, the study was underpowered to validate this result. Risk reduction shows a positive correlation with increasing age.

3.3. Aquatic Competencies and Acquisition of Skills

A wide range of aquatic competencies were explored (Table 4). Comparison was difficult as each study either employed their own definition of individual aquatic competencies or did not include a definition [51–55,57–59,61,62]. The protective benefit of an individual aquatic competency was not explored in the target age group. Common themes suggest key aquatic competencies for a 2–4 year old to survive a fall into a body of water or reduce the injury severity (either returning to the edge, exiting the pool or maintaining body position with head above water until assisted recovery) include, propulsion/locomotion (1 m), flotation/buoyancy, water familiarization, submersion and water exits [51–55,57–59,61,62].

The acquisition of age-appropriate skills was possible [51,52,54,55,57–59,61,62]. The younger the age at which children started lessons, the earlier the child was able to attain aquatic competencies within their developmental capabilities [52], noting the younger the child, the greater the potential dose–response (that is the number of lessons) required to acquire the skill(s) [52] (Table 5).

Table 4. Water competencies explored.

Aquatic Competency [1]	Anderson and Rodriguez [52]	Asher et al. [58]	Blanksby et al. [59]	Brenner et al. [55]	Bugeja and Franklin [53]	Costa et al. [54]	Erbaugh [61]	McGraw [62]	Olaisen et al. [51]	Parker and Blanksby [57]
Deck Behavior		X							X	
Entry	X	X		X		X	X		X	
Exit		X							X	
Water Familiarization	X	X	X	X	X	X	X	X	X	X
Submersion	X	X	X	X				X	X	X
Submersion only		X	X	X				X	X	X
Swim Underwater	X								X	
Retrieve Object	X	X					X			
Breath Control	X	X	X				X		X	X
Body Position		X	X			X	X	X	X	
Buoyancy/Flotation		X	X	X		X	X		X	X
Vertical		X				X	X		X	
Horizontal: Front		X	X			X	X		X	X
Horizontal: Back		X	X	X		X	X		X	
Propulsion		X		X			X		X	
Kicking—Front	X	X	X			X	X		X	X
Kicking—Back		X	X			X	X		X	X
Locomotion: Front	X	X	X	X			X		X	X
Locomotion: Back	X	X					X		X	
Endurance	X			X					X	
Water Safety Skills	X	X		X			X		X	
Recovery to edge		X		X			X		X	
Treading Water	X								X	

[1] Complete list of water competencies can be found in Table S3.

Table 5. Ability to acquire water competencies.

Author	Cohort	Competencies Achieved
Anderson and Rodriguez [52]	3 years ($\bar{x}$ = 3.4), n = 95 4 years ($\bar{x}$ = 4.4), n = 71	Children aged 3 to 4 years were able to reach level 1 competency. This included: jump into water, put head in water without goggles, pencil jump from pool deck, tread water for 1 min, swim underwater for 16 feet, swim underwater and retrieve rings from depth of 6 feet, swim 38 feet in prone, lifting head up to breathe. The younger the starting age, the younger the age at which the child reached level 1 proficiency.
Asher et al. [58]	24–42 months, n = 109	All three skill sets were achievable in 24–42 month children: 1. Out of water safety behavior. 2. Swimming ability included eight items, and these were " . . . 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 included " . . . water recovery ability to stand up when dropped from above water and ability to jump in and swim to edge of pool . . . ".
Blanksby et al. [59]	2–4 years, n = 123	Children could obtain level 2 by 4 years: Level 1: Water/teacher confidence, be totally happy in the water, buoyancy—able to kick with kickboard by sell with or without bubble, submerging—complete submersion on own without hesitation, blowing bubbles—blow bubbles with whole face in water. Level 2: Back float—stretched body, front float—stretched body, kicking with board (10 m)—back and front, on front incorporating breathing—lifting head up and down, while keeping shoulders in water, swim 5 m—preferably lifting head once for breath, torpedo—reasonably straight legs.
Brenner et al. [55]	1–4 years, n = 195	Formal swimming Lessons n = 37 Liked water n = 153 Comfortable in water n = 150 Comfortable submerging whole head n = 70 Float on back 10 s n = 25 Swim on stomach 15 feet n = 16 Jump in a pool/swim 5 feet/back to wall n = 16
Costa et al. [54]	4.39 years (±0.49 years), n = 98	Combined movements 56.6% of time achieved Glides 81.3% of the time achieved Breath control 100% of time achieved Skills of significant predictors included: body position at ventral gliding (Sk5, r = 0.467), body position at dorsal gliding (Sk6, r = 0.441), leg kick with breath control at dorsal body position with flutter boards (Sk11, r = 0.417) and without any flutter device (Sk12, r = 0.413). All 17 skills outlined in study were possible to be acquired by the 4 year old children at various levels.
Erbaugh [61]	2.5–5.5 years, n = 126	Locomotion front, n = 126 Locomotion back, n = 126 Kicking, n = 126 Entry: Jump, n = 126 Diving, n = 126 Ring puck up, n = 126
McGraw [62]	0–30 months, n = 42	Submerged in prone position without support, n = 42 Submerged in supine position without support, n = 42
Olaisen et al. [51]	3–5 years, n = 44	Average-unadjusted skill acquisition improvement was 12.3 skills (95% CI ranging from 10.0 to 13.0) (see supplementary one for full list of skills)
Parker and Blanksby [57]	2 years, n = 14 3 years, n = 57 4 years, n = 77	Children could obtain Level 2 by 4 years: Level 1: Water/teacher confidence, be totally happy in the water, buoyancy—able to kick with kickboard by sell with or without bubble, submerging—complete submersion on own without hesitation, blowing bubbles—blow bubbles with whole face in water. Level 2: Back float—stretched body, front float—stretched body, kicking with board (10 m)—back and front, on front incorporating breathing—lifting head up and down, while keeping shoulders in water, swim 5 m—preferably lifting head once for breath, torpedo—reasonably straight legs

3.4. Quality Assessment

Methodological limitations included a lack of consistency in the age targets for each study, which made comparative analysis challenging. For studies that examined the effectiveness of the intervention (the acquisition of aquatic competencies) [53,55,56,58,60], measures of effectiveness were challenging as no included study reported results based on objective morbidity or mortality reduction figures, and no significant changes were reported. This could be primarily attributed to results based on numbers too small to definitively assess between-group differences and most studies grouping ages differently. While five studies included objective data [52,53,56,57,60], most relied on self-reported knowledge, attitudes and behavior. As fatal drowning incidents are infrequent events (however more frequent in the given age group than other age groups), including data on non-fatal drowning would make statistical analyses and evaluations more reliable. Such data can facilitate evaluation of population-level interventions by providing an objective measure of drowning.

The prospective studies [51,54,58,61,62] were limited by a short follow-up period preventing capacity for studies to demonstrate sustained effects of acquiring aquatic competencies, as well as measurement bias associated with self-reported data, recall bias and lack of consideration of relevant confounders.

Additional limitations to the studies included the lack of consistent measures of exposure, lack of clarity around skills acquisition, limited age specific data (i.e., 2 years vs. 3 years vs. 4 years), small sample size, lack of dose–response relationship and inconsistent skill level testing across age groups [34,63–68].

4. Discussion

This review identified there is rudimentary evidence suggesting aquatic competencies hold benefit for the reduction of drowning risk. However, there is no evidence in support of, or against, the reduction in injury severity for children under the age of 4 years. Young children are not adults in miniature; they grow and mature under the influence of individual biological and environmental factors. Their psychological, physiological and biomechanical responses vary to exercise of different intensity, duration and frequency across their lifespan. Neurodevelopment and motor milestones are predominantly influenced by genetic factors driving maturation of the neurological system [67]. While this is acknowledged, environmental factors must not be underestimated for their significant role in the process of social and adaptive skill acquisition in children [67].

As treatment paradigms vary according to various factors, it is important to appreciate the role aquatic competencies could play in reducing and preventing drowning. In order to establish a suitable intervention for the prevention of childhood drowning, drowning risk factors must be identified. The Haddon Matrix [69,70] highlights the dynamic nature of a drowning event, reinforcing the need for a multi-layered approach to interventions [71,72], including incorporating aquatic competencies into drowning prevention (Table 6).

Table 6. Haddon's Matrix—pediatric drowning.

	Host	Vehicle (Agent or Vector)	Environment
Pre-event (Primary)	Teach children 2–4 years to swim	Do not leave attractant objects in pool after use	Fence the pool with 4-sided fencing
	Teach parent about water safety	Empty wading pool after use	Limit access from house to yard Ensure gate is self-closing and not propped open
Event (Secondary)	Never leave child in water alone or in the care of a sibling	Provide child with approved flotation device	Install pool/gate alarm Sign with CPR instructions
Post-Event (Tertiary)	Learn CPR	Healthcare and social resources for rehabilitation	Parent and child education on water safety devices

From the review, it was found that the understanding of aquatic competencies and the interrelationship to neurodevelopmental readiness was absent. The literature contains no definitive research to an optimum age and also what swimming competencies would be needed to prevent drowning [35]. There is evidence to suggest that children aged between 2–4 years may be less likely to drown if they have had swimming lessons [26,73]. Many of these studies were small in sample size and the definition of what aquatic competencies are needed to prevent drowning were not well defined [26]. The dose–response relationship is related to the acquisition of motor milestones; however, in this age group, it is yet to be fully understood. This includes exposure to aquatic environments, length or duration of exposure and frequency. The decision to introduce infant/toddler aquatic participation is a complex one, which not only relies on the neurodevelopmental maturation and milestone acquisition but also on qualitative progress of specific skills (ability and fluency) that are enhanced by continued participation [31,59,63–66,73].

Social media is replete with videos of babies and toddlers falling into pools and appearing to "self-rescue" or float on their backs. Such tools are used by swim instructors to advertise their programs

with the suggestion of such courses of instruction teaching the skills to be able to "drown-proof" infants and toddlers [74]. The findings of the current systematic literature review and the position of other leading organizations [21,75,76] reinforce that while teaching aquatic competencies to children 2–4 years of age may confer basic motor skills for water, infants cannot be expected to learn the elements of water safety or necessarily how to appropriately react in an aquatic emergency [75].

Recommendations against swimming lessons for children under the age of 4 years stem from the theory that children who are exposed to water in the early years may have an increased risk of drowning attributed to a decrease in the child's fear of water and may also relate to a decrease in adult supervision. Importantly, there is no support in the analysis of the literature that teaching young children to swim increases the likelihood of drowning (both fatal and non-fatal) by encouraging a false sense of security in children around the water, or by increasing the attractiveness of the water to them [58]. Larger, control-based studies are needed to more clearly define the relationship between swimming lessons and drowning risk in the pediatric population. Stronger evidence is required to formulate changes to and improve policy that will advance drowning prevention efforts and create an evidence-informed best practice guideline. While a consistent definition of drowning has been formalized along with recommended guidelines for uniform reporting of data from drowning [7,40,41,46], there is a need for future studies to use consistent terminology. Thus, there is a need for the development of guidelines for clarity and comparability in scientific communications of aquatic competencies, particularly when discussing fatal and non-fatal incidents. Usage of other terminology such as "swimming ability", "water competency or skill", "formal swimming lessons" and "learning to swim" highlights the need for standardization of terminology.

There were 129 studies excluded from this systematic review, principally due to study design and/or methodical limitations. Peer-reviewed literature from programs in Bangladesh were flagged by the exclusion criteria (mainly due to age composition and measure outputs). A significant number of studies were also excluded as they were not primary analytical studies. These papers shared a wide view on the importance of swimming lessons and the acquisition of aquatic competencies; however, interpretation of their findings or opinions must be met with caution due to either their methodological limitations or the bias (limited empirical evidence) supporting their findings. From the review, there was limited evidence to support (1) the acquisition of aquatic competencies reduces the burden of drowning in children 2–4 years and (2) what aquatic competencies children aged 2–4 years are capable of learning effectively. This reinforces the need for well-designed, case-control studies that address three important areas:

1. Do children 2–4 years display the neurodevelopmental readiness and are capable of acquiring aquatic competencies?
2. What aquatic competencies can 2–4 years acquire satisfactorily?
3. Do these aquatic competencies provide any protection or reduce the burden of drowning in the given age group (either as a sole prevention technic or in conjunction with other primary and secondary prevention measures know to have effectiveness in the age group), both in terms of death reduction and a reduction in injury severity in non-fatal events?

Anderson and Rodriguez [52] propose the limitations in neural maturation as an explanation for the failures of young infants to profit immediately from exposure to a new skill. Studies have been directed towards understanding the process of developmental readiness to learn motor skills; however, no study has linked the optimal readiness for a child to learn aquatic competencies [61,64,65]. Understanding the developmental readiness of the pediatric population to learn specific aquatic competencies is needed, adding to the argument that aquatic competencies should be classed as a fundamental movement in childhood development in their own right.

Limitations

The limitations of the included literature presented in the review introduce an equivocal appreciation for the findings. Although evidence supports aquatic competencies having a protective quality in the reduction of drowning risk for this age group, stronger evidence is required in determining age-appropriate skills directly relevant. Limitations included the lack of consistent measures of exposure, lack of clarity around skills acquisition, limited age specific data, small sample size, lack of dose–response relationships and inconsistent skill level testing across age groups. It must be appreciated there is a large neurodevelopmental difference between a child of 2 years of age and 4 years of age [34,63–68], specifically their ability in an aquatic environment.

Methodological limitations between articles made comparative analysis challenging. Measures of effectiveness were limited as no study reported results based on objective morbidity or mortality reduction figures, and no significant changes were reported. As discussed in the review, this could be attributed to study size numbers being too small for between-group analysis. All prospective studies [51,54,58,61,62] were limited by short follow-up periods, hindering demonstration of competency skills, and introducing measurement bias associated with self-reported data, recall bias and lack of consideration of relevant confounders.

This study itself has limitations, primarily driven by the limited empirical literature available. The method employed by the study and the inclusion/exclusion criteria included only peer-reviewed literature. Studies published outside the study timeframe, in languages other than English and in grey reports were also not included for analysis; possibly omitting supporting evidence. With the small number of studies included, limited exploration of confounding factors was possible. Although the study was limited in its findings, it highlights the need for further research to support evidence-informed practice that identifies aquatic competencies, which reflect the neurodevelopmental readiness of children aged 2–4 years.

The acquisition of aquatic skills through the learning portal of swimming lessons in the general population introduces many confounding factors, which multiple studies find difficult to address. Swimming lessons are generally attended by those of a higher socioeconomic index [77]. It is one assumption that this cohort, in general, would also be attending other social or education opportunities, which could also increase gross motor maturation and/or decrease drowning prevention risk [33]. A low socioeconomic index of an individual in itself has been reported to increase the relative drowning risk of individuals [78]. Families with multiple young children may also be disproportionally affected by attendance at traditional swimming lessons. The inclusion of randomized control or case control literature in this literature review attempts to minimize the confounding influence and strengthen evidence supporting the acquisition of aquatic competencies in the given age group. Moving forward, for an evidence-informed best practice to be established, an increase in empirical evidence addressing these potentially confounding factors is required.

5. Conclusions

In conclusion, this systematic review of the literature found that aquatic competences have the potential to prevent drowning; however, more work is needed to understand the skills required, the dose–response and neurodevelopmental appropriateness of the aquatic competencies. While aquatic competencies are able to be taught to young children 2–4 years of age, no child should be considered "drown-proof", as children cannot be expected to learn the elements of water safety or necessarily save themselves in an aquatic emergency. Young children are not adults in miniature and supervision of children is required; however, developing aquatic competencies was not found to increase the risk of drowning.

Supplementary Materials: The following are available online at http://www.mdpi.com/2313-576X/6/2/31/s1. Table S1: Search methodology including databases and search terms used. Table S2: List of references deemed relevant to study design of systematic literature review. Table S3: Detailed water competencies.

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