

## Accepted Manuscript

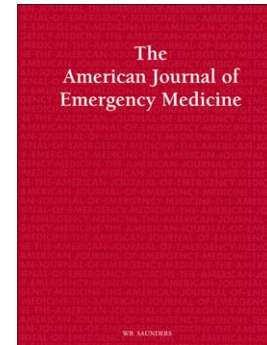
Drowning timeline: a new systematic model of the drowning process

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**Title**

Drowning timeline: a new systematic model of the drowning process

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**Short running head**

Drowning timeline

Drowning is one of the major causes of trauma [1]. Estimates indicate 372,000 deaths from drowning occur per year worldwide. However, the real figure is likely to be much larger since many cases are frequently unreported. For example, in low- and middle-income countries, many victims of drowning never make it to the hospital [1], preventing the official recording of the incident. In high-income countries, inconsistent use of International Classification of Disease codes or misinterpretation of drowning deaths at the hospital, result in some cases of fatal drowning not being classified as such [2],[3]. Furthermore, since drowning statistics are typically derived from resuscitation attempts [4] and hospitalizations, the real burden of drowning is further underestimated because such sources of information exclude most non-fatal cases.

Despite continuous advancements in policy, standardized drowning data collection systems are still lacking. Issues remaining include i) marked differences in the definitions, terminology and data collection methods used by local, national, and international agencies [5,6], and ii) lack of consistent bilateral communication of drowning data between prevention, rescue and life-support services and downstream care entities. In addition to contributing to the underreporting of drowning cases, this lack of a global approach reduces our understanding of the drowning process and obstructs data comparison, effectively compromising the outcome of drowning events [3].

Injury prevention models such as the Haddon Matrix [7] have been used in the context of drowning, in an attempt to address the issues abovementioned. However, in 2002 drowning was redefined as “the process of experiencing respiratory impairment from submersion or immersion in liquid”, with three possible outcomes: death, survival with morbidity and survival with no-morbidity. This redefinition was adopted by the WHO in 2005 [8]. The wider scope of drowning brought about by the new definition, and the fact that these models have been developed for other types of trauma, means that they can no longer be considered efficient for the systematic interpretation of the drowning process.

In this context, the proposed drowning timeline aims at reframing drowning by providing a detailed description of the revised phases of the drowning process,

highlighting triggers, actions and interventions in a concise manner, with a strong focus on preventive measures.

## **BUILDING CONSENSUS**

Studies show there is little consensus among authors regarding drowning terminology and the time and importance of the actions taking place throughout the entire drowning process [5,6]. With that in mind, a group of trauma researchers with expertise in drowning met to design a new model for the systematic interpretation of the drowning process. A first draft of the model was submitted to a working group of 57 drowning, flood, and crisis management researchers and practitioners, from different agencies and countries. The working group crosschecked the robustness of the model against real drowning cases from different aquatic scenarios, and suggested improvements and corrections. A revised version was presented and debated at the World Conference on Drowning Prevention 2015 in Penang, Malaysia, and subsequent adjustments were made following further discussion with experts.

## **DROWNING TIMELINE**

The iterative process used for the establishment of the model here proposed allowed the clarification of all drowning phases, their triggers and associated actions, as well as the establishment of their chronological sequence in alignment with the experts' perception of the sequence of events during the drowning process. The new systematic model is presented in Figure 1, and its components are detailed in Table 1.

## **FUTURE IMPACT**

As with other types of trauma, the lack of clear-cut distinctions between pre-event, event and post-event, as well as between triggers, actions and interventions, hampers the systematic collection of drowning-related data. This, in turn, has severe

impacts on the quality of the estimates of the global burden of drowning, and consequently on the effectiveness of drowning prevention strategies.

The new systematic model of drowning here presented resolves the inadequacies of previous injury prevention models when applied to the drowning context, and reinforces the primary role of prevention in the effort to tackle drowning injuries worldwide. By reflecting the opinion of a large number of experts in drowning, it also represents a major step towards a global consensus on the chronological sequence of the drowning process. Additionally, by specifying unambiguous definitions of triggers, actions and interventions, it provides the necessary tools for a more effective deployment of resources, better coordination between all drowning prevention, rescue and treatment actors, establishment of adequate prevention strategies, and for the measurement of future cost/benefit ratios related to outcomes in terms of public health, financial, political and social impacts.

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## References

- [1] World Health Organization. Global Report on Drowning. World Health Publications; 2015.
- [2] Lu T-H, Lunetta P, Walker S. Quality of cause-of-death reporting using ICD-10 drowning codes: a descriptive study of 69 countries. *BMC Med Res Methodol* 2010;10:30. doi:10.1186/1471-2288-10-30.
- [3] Szpilman D, Bierens JJLM, Handley AJ, Orłowski JP. Drowning. *N Engl J Med* 2012;366:2102–10. doi:10.1056/NEJMra1013317.
- [4] Idris AH, Berg RA, Bierens J, Bossaert L, Branche CM, Gabrielli A, et al. Recommended guidelines for uniform reporting of data from drowning 2003.
- [5] Papa L, Hoelle R, Idris A. Systematic review of definitions for drowning incidents. *Resuscitation* 2005;65:255–64. doi:10.1016/j.resuscitation.2004.11.030.
- [6] Sempstrott J, Slattery D, Schmidt A, Penalosa B, Crittle T. Systematic Review of Non-Utstein Style Drowning Terms. *Annals of Emergency Medicine* 2011;58:S321. doi:10.1016/j.annemergmed.2011.06.456.
- [7] Haddon W. The changing approach to the epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based. 1968. vol. 5. BMJ Publishing Group Ltd; 1999.
- [8] van Beeck EF, Branche CM, Szpilman D, Modell JH, Bierens JJLM. A new definition of drowning: towards documentation and prevention of a global public health problem. *Bull World Health Organ* 2005;83:853–6.
- [9] Brenner RA, Saluja G, Smith GS. Swimming lessons, swimming ability, and the risk of drowning. *Injury Control and Safety Promotion* 2003;10:211–5. doi:10.1076/icsp.10.4.211.16775.
- [10] Wallis BA, Watt K, Franklin RC, Taylor M, Nixon JW, Kimble RM. Interventions associated with drowning prevention in children and adolescents: systematic literature review. *Injury Prevention (1353-8047)* 2015;21:195–204.

[11] Leavy JE, Crawford G, Portsmouth L, Jancey J, Leaversuch F, Nimmo L, et al. Recreational Drowning Prevention Interventions for Adults, 1990–2012: A Review. *J Community Health* 2015;1–11. doi:10.1007/s10900-015-9991-6.

[12] Fink G, editor. *Stress Science*. Oxford: Academic Press; 2010.

## Legends

Figure 1 – The drowning timeline. Triggers, actions and interventions are arranged to reflect the real chronological sequence of the drowning process. Differences in the size of shapes are only present to improve readability, and do not reflect differences in cost or effort. The overlap between the reaction and mitigation actions represents the diffuse transition between the two actions. This occurs when the victim is still being rescued, but some of the interventions of the rescuer can already be regarded as mitigating interventions. See Table 1 for a detailed description of all components of the drowning timeline.

Table 1 – Detailed description of all components of the drowning timeline.



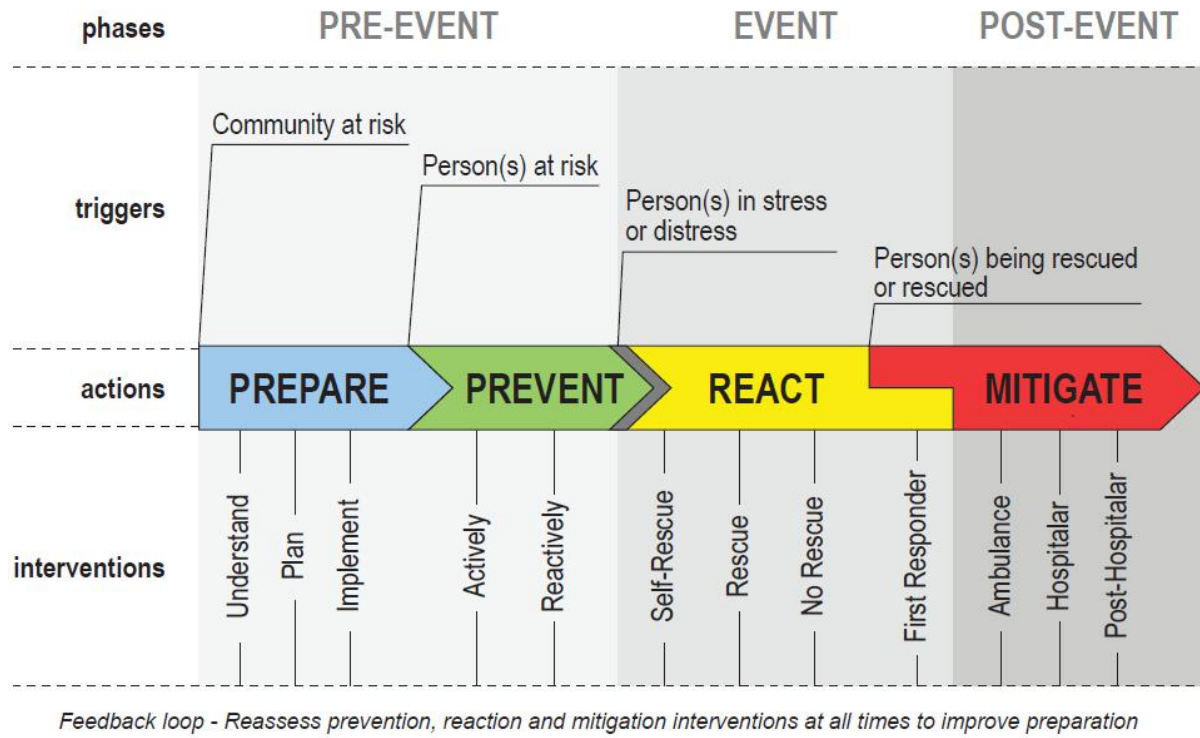


Figure 1

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Table 1

PHASES:	PRE-EVENT		EVENT	POST-EVENT
ACTIONS:	Prepare [9](a)	Prevent [1,10,11]	React	Mitigate
TRIGGERS	Community at Risk	Person(s) or a group at risk	Person(s) in stress or in distress [3,12]	Person(s) being rescued or rescued
Definitions	<ul style="list-style-type: none"> <li>• Actions directed at communities at risk, taken before an incident</li> <li>• Aimed at improving effectiveness of Prevent, React and Mitigate actions</li> </ul>	<ul style="list-style-type: none"> <li>• Actions directed at risky environments and users, and taken before an incident</li> <li>• Aimed at stopping the drowning event from occurring</li> </ul>	<ul style="list-style-type: none"> <li>• Actions directed at a person (or group) in stress or distress and taken after an incident while in water</li> <li>• Aimed at interrupting the progress of drowning once it started</li> </ul> <p>(b)</p>	<ul style="list-style-type: none"> <li>• Actions directed at a specific person, or group, taken while performing the rescue or immediately after the rescue</li> <li>• Aimed at reducing the impact of the injury on the victim(s)</li> </ul> <p>(c)</p>
Interventions	<ul style="list-style-type: none"> <li>• <b>Understand</b> the problem</li> <li>• <b>Plan</b> the best strategy to fight the problem</li> <li>• <b>Implement</b> the plan and verify its effectiveness</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Active</b> prevention: actions directed to a specific area or detection of risky behaviors at the scene</li> <li>• <b>Reactive</b> prevention: actions directed at specific individuals or groups to stop an imminent danger</li> </ul>	<ul style="list-style-type: none"> <li>• <b>self-rescue</b></li> <li>• <b>rescue</b></li> <li>• <b>no-rescue</b></li> </ul>	<ul style="list-style-type: none"> <li>• During the event phase actions are usually performed by professionals, such as lifeguards or first responders</li> <li>• During the post-event phase includes all interventions related to provision of health care and can be categorized as: <ul style="list-style-type: none"> <li>○ local (ambulance),</li> <li>○ at hospital; and</li> <li>○ post-hospital interventions</li> </ul> </li> </ul>
Examples	<p><b>Preparation to prevent (c)</b> consists of education in its different forms usually away from aquatic setting, e.g. educational videos, billboards, school activities and others. <b>Preparation to react</b> consists of learning how to react to danger situation to yourself or others in an aquatic setting, e.g. learn how to swim, recognizing a potential drowning victim, and/or rescue techniques.</p> <p><b>Preparation to mitigate</b>, consists of training in and outside an aquatic setting, including learning drowning and CPR protocols.</p>	<p><b>Active</b> interventions include:</p> <ul style="list-style-type: none"> <li>• placing a warning signage at specific risky areas,</li> <li>• identifying environment hazards or behaviors.</li> </ul> <p><b>Reactive</b> interventions include:</p> <ul style="list-style-type: none"> <li>• whistling to a bather or a group directing them to safety,</li> <li>• removing bather or group from the dangerous situation before the event of drowning starts (risky activities).</li> </ul>	<p><b>Self-rescue</b> occurs when the person is able to get out of the difficult situation without external assistance. <b>Rescue</b> occurs when the person is assisted by someone else (can be a relative, a friend, a lifeguard). <b>No-rescue</b>, is when help is needed but not provided.</p>	<p>During the <b>event</b> mitigating interventions may include:</p> <ul style="list-style-type: none"> <li>• opening the airway while rescue is taking place;</li> <li>• a first responder performing in-water ventilations,</li> <li>• providing oxygen using a facemask while extricating an individual from a water disaster like a flood, but still in a boat and in danger.</li> </ul> <p>During the <b>post-event</b> phase, mitigation interventions may include:</p> <ul style="list-style-type: none"> <li>• a drowning victim being assisted in a critical situation at the beach;</li> <li>• specific health care provided during transportation to a ER and hospitalization;</li> <li>• home care rehabilitation (after release from hospital) which can include physical and psychological assistance.</li> </ul>

a) All forms of preparation can be taught both to the general public to professionals, but the contents and responsibilities might differ.

b) Initiated by a stressful condition, when a person feels at risk of drowning, followed by a distress situation when the ability to rationally cope with the stressful condition is overwhelmed; Reaction will only stop with the extrication from the water/danger

c) Casualty assessment during the event phase induces in-water mitigation actions. Does not take place in the water during self-rescue or no rescue interventions. Mitigation actions in the post-event phase are initiated only after extrication from immediate danger has ended.

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