# Drowning and Near-Drowning Involving Children: A Five-year Total Population Study From the City and County of Honolulu

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**Abstract:** A study of all serious childhood immersion accidents (both drowned and near-drowned cases) is reported from Hawaii. This is a total population-based survey of 140 consecutive cases (0–15 years) occurring during the five-year period 1973–1977. Age-specific, sex-specific, and osmolality-specific (salt versus fresh water) data are presented both for survivors and fatalities. The overall annual drowning rate of 3.1 per 100,000 children at risk is low, for a water-oriented society. The survival rate following loss of consciousness in the water is 73 per cent. There is no evidence from this study that osmolality affected the probability of survival. The rank order of importance of drowning sites is swimming pools, surf, sheltered salt water bathing, domestic bath tubs, fresh water streams, salt water canals, and garden fish ponds. Specific accident rates, by sex, outcome, and site of immersion are also presented. No secular trend in the rate of drowning was observed in this study. Comparison with the only other available total population survey (Australia) of childhood immersions reveals common epidemiological and demographic patterns in modern urban societies and suggests that safety regulations play a role in reducing swimming accidents and fatalities in children. (Am. J. Public Health 69:450–454, 1979.)

Drowning statistics, specific for sex, age and differing water osmolalities, are essential for the interpretation of epidemiological secular trends; for the planning and subsequent interpretation of preventive programs; and for the interpretation of differing intensive care and management regimens. There are a number of excellent studies of childhood drowning fatalities,[1–3] but in view of the possible implications of neurological damage in survivors[4, 5] it is obvious that more detailed knowledge of this problem is required. Survival rates which are age-, sex- and osmolality-specific can only be obtained from total population studies of all serious immersion accidents, which include both survivors and fatal cases. Such baseline data are now available for fresh water immersion accidents in Australia.[6–8] To provide further essential data of this nature we report here a total population study from the Island of Oahu (City and County of Honolulu) in the State of Hawaii, for the five-year period 1973–1977 inclusive.

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## *Methods*

### Case Finding

Details of every child who had suffered a serious immersion accident, as defined below, irrespective of type of water, have been included. To obtain such data we have used three sources of cases:

- Complete searches of all relevant hospital admission registers and records departments of the five major hospitals.* Five other hospitals in the City of Honolulu refer

*All cases coded (H-ICDA) for 994.1—drowning, immersion, effects of submersion, and for E910—accidental drowning or submersion, were checked in the Kauikeolani Children's Hospital, Queen's Medical Center, Kapiolani Medical Center, Kaiser Foundation Medical Center, and Tripler Army Medical Center.

serious immersion childhood cases to the Kauikeolani Hospital. The hospitals searched comprise the sites of definitive care for seriously-immersed children who are alive (or deemed to be potentially resuscitatible) at the time of rescue;

- Complete searches of the forensic and coroner autopsy files of the Chief Medical Examiner, City and County of Honolulu. There is a statutory requirement that all cases of fatal immersion, irrespective of time of survival, be reported to the Chief Medical Examiner;
- Personal approaches to consultant pediatricians and selected private physicians on the Island of Oahu.

For many cases traced in this way, these sources proved mutually inclusive.

**Definitions**

*Serious Immersion Accident:* Alteration of respiration (in 76 per cent of cases the child was totally apnoeic), and admission to hospital or death. We have calculated separate epidemiological indices for fatal cases and for survivors who were apnoeic and unconscious following rescue, as well as for all serious immersion accidents.

*Fresh Water:* Water with an osmolality equal to or less than that of human plasma. This included swimming pools (all were chlorinated in this series), fresh water streams, irrigation ditches and flumes, domestic bathtubs, and ornamental fresh water ponds.

*Salt Water:* This included the surf, sheltered sea, bays, and water in tidal sea water canals.

*Child:* An individual under the age of 16 years.

*Fatality:* The child died in the water, or died after rescue because of the direct effects of cerebral anoxia or respiratory complications. Six children died following rescue (time range of six hours to seven days following extraction from the water). We have called this group "delayed death subsequent to near-drowning" following the convention of Modell.[9]

*Survivor:* An individual in whom spontaneous respiration was permanently reestablished, and who did not die directly or indirectly as a result of cerebral anoxia or respiratory complications. The term "near-drowning" refers to the event experienced by a survivor.

*Locale:* Oahu is tropical, with sunny weather, and is situated at 158° West Longitude and 21° North Latitude (January: Avg. min. temp. 22.4° C, avg. morning humidity 80 per cent, 63 per cent avg. possible sunshine; July : Avg. max temp. 30.4° C, avg. morning humidity 64 per cent, 74 per cent avg. possible sunshine).[10] Sea water temperatures range from 23.9° C (March) to 27.8° C (August). The climate is insular, and no site on the island is more than 12 miles from the sea. Sea bathing includes sea lagoons, through Waikiki Beach which tends to have moderate surf to Waimea Bay where some of the biggest ridden surf in the world is encountered. Swimming pools are popular, and there is an estimated pool/house ratio of 1:40.** Previous reports of drowning fatalities in Hawaii have been published.[11, 12]

The population encompassed by Oahu represents all social classes found in a mixed modern urban and rural county of 705,700 people. At the mid-survey point (1975) the population comprised 81.3 per cent of the resident population of the State of Hawaii. The exact population of children at risk, by age and by sex, was obtained from the Department of Planning and Economic Development, and from a 1975 Census Update Survey.[13] The population is cosmopolitan, with eight defined ethnic subgroups,[14] of which the largest representatives are Caucasians (39.2 per cent) and Japanese (28.3 per cent).

**TABLE 1—Serious Immersion Accidents in Childhood, City and County of Honolulu, 1973–1977**

| | Fresh Water | Salt Water | Total |
|---|---|---|---|
| Immersion fatalities | 20 | 11 | 31 |
| Immersion survivors, apnoeic and unconscious at rescue, hospitalized | 56 | 27 | 83 |
| Survivors, either not apnoeic or not unconscious at rescue, but admitted to hospital | 6 | 20 | 26 |
| TOTAL | 82 | 58 | 140 |

## *Results*

A total of 140 serious immersion accidents involving children (0–15 years of age) occurred in the five-year period 1973–1977 (Table 1). One hundred fourteen (81 per cent) of these were either dead or totally apnoeic and unconscious when extracted from he water. The overall survival rate, once consciousness was lost in the water, was 73 per cent. The proportion of males amongst those who died was 65 per cent (virtually identical with the figure of 66 per cent reported from a total population study in Australia).[6] Of the 31 children defined as drowning fatalities, 25 (81 per cent) were dead on removal from the water, with the remaining six either manifesting a heartbeat at the time of rescue or developing one following cardiopulmonary resuscitation. These six cases of "delayed death subsequent to near-drowning"[9] all remained in a virtual vegetative state following removal from the water but, in spite of vigorous intensive care management, died within six hours to seven days following rescue. No long-term survivor suffered significant brain damage. No cases of so-called "secondary drowning" were encountered.***

Table 2 shows the annual immersion accident rates for this population, by age, sex, and outcome per 100,000 children at risk for fresh water, salt water, and total immersions. The mortality rates are low, with fresh water rates approximately twice the observed rate for corresponding salt water immersions at all ages except infancy where bathtub immersions were common.

In contrast to other reports[15–17] which were not popu-

**Unpublished data: The Swim Pool Association of Hawaii.

***In this condition the child apparently responds well following initial extraction from the water, but due to the loss of pulmonary surfactant and probably alveolar pneumonocyte damage, subsequently develops catastrophic pulmonary decompensation, and dies from these effects after an intervening period of relatively good lung function.

**TABLE 2—Annual Immersion Accident Rates per 100,000 Age-specific Population at Risk,* by Sex and by Outcome for Fresh Water, Salt Water and Total**

| Age | Survivors | | | Drownings | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Total | Male | Female | Total | Male | Female | Total |
| | | | | *Fresh Water Immersions* | | | | | |
| Under 1 year | 9.2 | 13.1 | 11.1 | 3.1 | 6.5 | 4.7 | 12.3 | 13.6 | 15.8 |
| 1–4 years | 14.5 | 11.5 | 13.0 | 6.8 | 1.8 | 4.3 | 21.3 | 13.3 | 17.4 |
| 5–9 years | 5.9 | 3.1 | 4.6 | 1.8 | 1.3 | 1.5 | 7.7 | 4.4 | 6.1 |
| 10–15 years | 1.5 | 0.5 | 1.1 | 0.5 | 0.5 | 0.5 | 2.0 | 1.1 | 1.6 |
| TOTAL | 6.4 | 4.7 | 5.6 | 2.5 | 1.4 | 2.0 | 8.9 | 6.1 | 7.6 |
| | | | | *Salt Water Immersions* | | | | | |
| Under 1 year | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 |
| 1–4 years | 13.6 | 6.2 | 10.0 | 2.6 | 1.8 | 2.2 | 16. | 8.0 | 12.2 |
| 5–9 years | 2.4 | 4.4 | 3.4 | 0.6 | 0.6 | 0.6 | 3.0 | 5.0 | 4.0 |
| 10–15 years | 3.6 | 1.6 | 2.6 | 1.5 | 0.5 | 1.1 | 5.1 | 2.1 | 3.7 |
| TOTAL | 5.3 | 3.5 | 4.4 | 1.4 | 0.8 | 1.1 | 6.6 | 4.3 | 5.5 |
| | | | | *All Immersions* | | | | | |
| Under 1 year | 9.2 | 13.1 | 10.7 | 3.1 | 6.5 | 4.7 | 12.2 | 19.6 | 15.4 |
| 1–4 years | 29.8 | 17.8 | 23.9 | 9.4 | 3.6 | 6.5 | 39.7 | 21.3 | 30.4 |
| 5–9 years | 8.3 | 7.5 | 7.9 | 2.4 | 1.9 | 2.1 | 10.7 | 9.4 | 10.1 |
| 10–15 years | 8.2 | 2.7 | 5.5 | 2.0 | 1.1 | 1.6 | 10.2 | 3.8 | 7.1 |
| TOTAL | 13.2 | 8.4 | 10.9 | 3.9 | 2.3 | 3.1 | 17.1 | 10.6 | 14.0 |

*Figures rounded to nearest tenth

lation-based, there was no significant difference between the overall survival rate in fresh water (75 per cent) when compared with that for salt water (69 per cent). No age or sex differences in survival rates were demonstrable.

Table 3 shows the site of the drowning and near-drowning accidents in all 140 cases. Of these, 58 (41 per cent) occurred in swimming pools, and 41 (29 per cent) occurred in the surf.

The age-specific immersion accident rate for 1 to 4 year olds in swimming pools is 13.5 per 100,000 at risk, and that for infants in domestic bathtubs is 9.5 per 100,000.

Because of the dramatic increase in life-threatening childhood immersion accidents in other centers,[6] an analysis of possible secular trends was also undertaken. Table 4 shows childhood accidents by year of occurrence and by outcome, cross-indexed to water osmolality. No trend is apparent.

## *Discussion*

From the viewpoint of preventive medicine, it is essential that childhood trauma statistics report both fatal and non-fatal immersion accident cases. In serious immersion

**TABLE 3—Site and Type of Childhood Drowning and Near-Drowning Accidents, 140 Consecutive Cases, City and County of Honolulu, 1973–1977, by Sex and by Outcome**

| Water Osmolality | Site of Accident | Survivors | | | Drownings | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | Female | Total | Male | Female | Total | Male | Female | Total |
| Fresh | Swimming pool | 27 | 22 | 49 | 7 | 2 | 9 | 34 | 24 | 58 |
| | Stream | 1 | 0 | 1 | 4 | 3 | 7 | 5 | 3 | 8 |
| | Bathtub | 5 | 2 | 7 | 1 | 1 | 2 | 6 | 3 | 9 |
| | Reservoir | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| | Fish pond/water bucket | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 4 |
| TOTAL | | 35 | 25 | 60 | 13 | 7 | 20 | 48 | 32 | 80 |
| Salt | Surf | 22 | 12 | 34 | 4 | 3 | 7 | 26 | 15 | 41 |
| | Sheltered bay | 5 | 6 | 11 | 1 | 1 | 2 | 6 | 7 | 13 |
| | Salt-water canal/salt pool | 4 | 0 | 4 | 1 | 0 | 1 | 5 | 0 | 5 |
| | Boating accident | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| TOTAL | | 31 | 18 | 49 | 7 | 4 | 11 | 38 | 22 | 60 |
| All Cases | | 66 | 43 | 109 | 20 | 11 | 31 | 86 | 54 | 140 |

**TABLE 4—Serious Childhood Immersion Accidents, City and County of Honolulu, by Year of Occurrence 1973–1977**

| Year | Survivors | | Fatalities | | Total |
|---|---|---|---|---|---|
| | Fresh Water | Salt Water | Fresh Water | Salt Water | |
| 1973 | 11 | 10 | 2 | 4 | 27 |
| 1974 | 13 | 16 | 6 | 4 | 39 |
| 1975 | 9 | 11 | 5 | 0 | 25 |
| 1976 | 17 | 5 | 3 | 2 | 27 |
| 1977 | 10 | 7 | 4 | 1 | 22 |
| TOTAL | 60 | 49 | 20 | 11 | 140 |

accidents, mortality figures reflect only one aspect of the problem, and ignore the potential chronic morbidity (i.e., hypoxic brain damage[4, 5, 18]) that can occur in surviors. The total immersion accident rate of 14.0 per 100,000 children at risk, reported here, is the first such U.S. Statistic based upon an unselected total population, and so cannot be compared to ratios reported in other studies. It is hoped, however, that it will form a reference baseline for future studies of what is one of the major killers of children after the first year of life.[7, 18, 19] The figure of 14.0 per 100,000 appears low for sophisticated Western urban populations, and compares favorably with a figure of 10.4 per 100,000 for Australian fresh water cases alone. If one considers only fatalities, the rate of 3.1 per 100,000 (salt and fresh water combined) is very low; comparative figures of 4.5 and 5.2 per 100,000 were observed in two total population studies in Australia;[6, 20] the latter figure must be considered a minimum estimate, as no salt water cases were included. This low figure for Hawaii, with no part of Oahu more than 12 miles from the sea and a high rate of swimming pool ownership, is of considerable interest. Pools in Hawaii are subject to strict safety regulations.[21] This reinforces earlier suggestive evidence that public health endeavors must look beyond raw estimates of swimming pool and surf exposure to specify the particular risk elements of childhood drowning accidents.[22] The mere presence of the water hazard itself is not necessarily a reliable indication of risk.

The wide range of childhood immersion accident rates by age emphasizes the importance of age-specific data to the planning of preventive programs (e.g., a rate of 3.8 for adolescent girls is dramatically different from the rate of 39.2 for preschool boys). For comparison with other reports, it is essential that osmolality-specific accident rates only be compared. Age- and sex-specific survival rates may differ markedly, depending on whether a child is drowning in salt or fresh water.

Fresh water drowning fatalities from Hawaii are low (2.0 per 100,000) compared with much higher rates reported from Australia (5.2 per 100,000). Salt water fatalities were surprisingly rare in childhood (1.1 per 100,000), in spite of extensive exposure and other attendant hazards,[23] and this heartening trend has also been documented elsewhere.[24] The failure to demonstrate, in this study, any difference between survival rates for salt water (0.7) and fresh water (0.75) lends further support to the hypothesis advanced by others,[25] that it is the degree of hypoxia itself which is critical in human clinical drowning in spite of the well-accepted differences in pathophysiological mechanisms of transalveolar water flow.[26–28]

A comparison of the Honolulu figures with those of the Brisbane Drowning Study[6, 8, 22, 29] suggests that safety legislation is effective. Both cities are of approximately equal size, both have a high pool/house ratio, both experience a hot tropical and subtropical insular climate, and the lifestyles of the indigenous populations have many points of similarity. The swimming pool fatality rate for Honolulu is 0.9 per 100,000 population at risk, compared with a rate of 2.6 from the Brisbane Drowning Study. Swimming pools in the City and County of Honolulu are fenced,[21] whereas those in the City of Brisbane are not,[22, 29] The definitive study (measuring childhood drowning rates sequentially before and after the institution of protective fencing around water hazards) has still not been undertaken or reported from any center.

Child trauma remains the foremost problem in preventive pediatrics,[30] and drowning and near-drowning comprise a major component of the problem;[2] further comparative studies of different populations will give added information on the relative importance of causal factors known to be important in childhood immersions. Only in this way can specific preventive compaigns be planned so as to achieve success.

## REFERENCES


1. Dietz PE and Baker SP: Drowning: Epidemiology and prevention. Am J Public Health 64:303-312, 1974.
2. Press, E, Walker J and Crawford I: An interstate drowning study. Am J Public Health 58:2275-2289, 1968.
3. Williams HD and Modell JH: Statistics and public health considerations, *in* The Pathophysiology and Treatment of Drowning and Near-drowning, (Ed.) JH Modell, Springfield, IL, Charles C. Thomas, pp 3-7, 1971.
4. Pearn JH: Neurological and psychometric studies in children surviving fresh water immersion accidents. Lancet 1:7-9, 1977.
5. Peterson B: Morbidity of childhood near-drowning. Pediatrics 59:364-370, 1977.
6. Pearn JH, Nixon J and Wilkey I: Fresh water drowning and near-drowning accidents involving children. A five-year total population study. Med J Aust 2:942-946, 1976.
7. Pearn J: Drowning in Australia: A national appraisal with particular reference to children. Med J Aust 2:770-771, 1977.
8. Pearn JH and Nixon J: Prevention of childhood drowning accidents. Med J Aust 1:616-618, 1977.
9. Modell JH: The Pathophysiology and Treatment of Drowning and Near-drowning. op. cit (3) Definitions and Descriptions, p 9.
10. Dept. Planning and Econ. Development (U.S.). The State of Hawaii Data Book 1977. A Statistical Abstract. Ref HA4007/ H356. Honolulu. Table 90, p 91. Table 93, p 93.
11. Moser RH: Drowning. Hawaii Med J 33:129-131, 1974.
12. Barrett O and Martin CM: Drowning and near-drowning: A review of ten years' experience in a large Army hospital. Milit Med 136:439-443, 1971.
13. Honolulu Community Action Program Inc. (1976). 1975 Census Update Survey. Oahu, Honolulu, Survey Marketing Services Inc. Table 2, p 13.
14. Dept. Planning and Economic Development (1977). op cit. (10) Table 12, Ethnic Stock p 25.
15. Eriksson R, Fredin H, Gerdman P, and Thorson J: Sequelae of accidental near-drowning in childhood. Scand J Soc Med 1:3-6, 1973

16. Fuller RH: The clinical pathology of human near-drowning. Proc Roy Soc Med 56:33-38, 1963.
17. Miles S: Drowning. Brit Med J, 3:597-600, 1968.
18. Fandel I and Bancalari E: Near-drowning in children: Clinical aspects. Pediatrics, 58:573-579, 1976.
19. Anon: Accidental drownings by age and activity. Stat. Bull Metropol. Life Ins. Co., 58:2-5, 1977.
20. Pearn JH and Thompson J: Drowning and near-drowning in the Australian Capital Territory. A five-year total population study of immersion accidents. Med J Aust 1:130-133, 1977
21. City and County of Honolulu, State of Hawaii. The Revised Ordinances of Honolulu 1969; as Amended 1970-1972 Cumulative Supplement Ord. 3508-4068, 1972. Article 28. Swimming pools p 208-210.
22. Pearn J and Nixon J: Are swimming pools becoming more dangerous? Med J Aust 2:702-704, 1977.
23. Allen RH, Eiseman B, Straehley CJ and Orloff BG: Surfing injuries at Waikiki. JAMA, 237:668-670, 1977.
24. Patrick, Bint and Pearn: Salt water drowning and near-drowning accidents involving children. Med J Aust (in press 1978).
25. Kristoffersen, MB, Rattenborg, CC and Holaday, DA: Asphyxial death: the roles of acute anoxia, hypercarbia and acidosis. Anesthesiology, 28:488-497, 1967.
26. Ritchie, BC: The physiology of drowning. Med J Aust 2:1187-1189, 1972.
27. Modell JH, Calderwood HW, Ruiz BC, et al: Effects of ventilatory patterns on arterial oxygenation after near-drowning in sea water. Anesthesiology, 40:376-384, 1974.
28. Nopanitaya W, Gambill TG and Brinkhouse KM: Fresh water drowning. Pulmonary ultrastructure and systemic fibrinolysis. Arch Path 98:361-366, 1974.
29. Pearn JH and Nixon J: Swimming pool immersion accidents. An analysis from the Brisbane drowning study. Med J Aust 1:432-437, 1977.
30. Kiefer NC: Accidents—the foremost problem in preventive medicine. Prev Med 2:106-122, 1973.

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