CHAPTER 2

DROWNING, INJURIES AND POOL SAFETY MANAGEMENT

In this chapter, the incidence rates of drowning, near-drowning and injuries associated with swimming pools, spas and similar recreational-water environments are discussed, together with contributory factors and preventive actions.

2.1 Drowning and near-drowning

2.1.1 Drowning

Drowning can generally be defined as death by suffocation due to immersion in water. It may be classified as either "wet" — where the victim has inhaled water — or "dry" — a less common condition, but one that involves the closing of the airway due to spasms induced by water. The actual physical action of drowning depends on the circumstances (see Box 2.1).

Box 2.1: Physical processes during drowning

Wet drowning: fresh water

A sufficient volume of fresh water entering the lungs will interfere with the process of external respiration by preventing the passage of gases between the alveoli and pulmonary capillaries. Haemodilution is then created by rapid absorption of the water into the blood. This in turn distorts the pH of the blood. In these circumstances, a cardiac arrest may occur within some 2–4 min after rescue.

Wet drowning: salt water

Salt water has the opposite effect of fresh water, but the same result often occurs. As salt water enters the lungs, water is drawn into the alveoli from the bloodstream by osmotic pressure, increasing the volume of fluid in the lungs. This in turn increases the viscosity of the blood, causing sluggish circulation, which eventually slows the heart rate to the point of a cardiac arrest. Cardiac arrest may occur up to 12 min after rescue.

Dry drowning

As a drowning person sinks and unconsciousness deepens, the individual continues to try to breathe. The impact of this is that water flows through the pharynx and stimulates the reflex, which triggers the larynx and epiglottis to close. With the trachea protected, water is diverted to the stomach. In most cases, it is found that less than 1 litre of fluid has entered the lungs of a drowning victim, compared with several litres of water swallowed.

Information concerning drowning is not systematically collected in all countries, nor is the same definition used among them. Data on deaths through drowning are available from the WHO mortality database; in general, however, accidents related to bathing waters and recreational activities are not separately recorded (WHO, 1996). Drowning statistics typically include suicides and domestic drownings (e.g., in bathtubs by both adults and children), as well as drowning following immersion during occupational and recreational activity.

Drowning typically accounts for a small but significant percentage of accidental deaths (e.g., 2% in Denmark; Steensberg, 1998), and overall incidence rates for death by drowning (all causes) have been estimated at around 6 per 100 000 by several authors (Plueckhahn, 1979; Quan et al., 1989). In the European Region, drowning accounted for less than 10% of the 280 000 deaths due to accidents in 1995 (WHO, 1996).

Most studies of accidental drowning have focused on children, and in some countries drowning is the leading cause of injury deaths among younger age groups (see, for example, Smith, 1995). Drowning is the second leading cause of injury death of infants and children less than 15 years of age in the USA. Statistics vary in publications, as there is no official source of data collection other than the National Electronic Information Statistics Source operated by the US Consumer Product Safety Commission (CPSC). It is generally recognized that in the USA:

- Sixty-seven per cent of all drownings occur in backyard pools, spas and hot tubs.
- The majority of drowning incidents have occurred while the child's supervisor assumed the child was safely indoors.
- A child can drown in less time than it takes to answer the telephone.
- A child can drown in as little as 5–8 cm of water after submersion for only 30 s.
- Children less than five years of age and young adults between the ages of 15 and 24 years have the highest drowning rates (see Table 2.1).
- Children less than one year of age most frequently drown in bathtubs and buckets.
- Children between the ages of one and four years most often drown in home or apartment swimming pools. Many of these children drown by entering the pool from their home through the unprotected side of the pool. In the majority of cases, the children were last seen in the home but were out of eye contact for only a moment, and the drowning child did not scream, yell for help or make a splash.

Table 2.1: Drowning statistics for the USA (per 100 000)

Ages (years)	**1997**		**1996**		**1995**	
	Deaths	**Rates**	**Deaths**	**Rates**	**Deaths**	**Rates**
0–4	516	2.69	533	2.76	596	3.05
5–9	234	1.19	223	1.15	222	1.16
10–14	215	1.13	225	1.19	242	1.29
15–19	349	1.83	388	2.08	442	2.43
20–24	316	1.80	327	1.86	348	1.93
25–29	298	1.58	291	1.53	292	1.54

Source: National Center for Health Statistics, 1998

Since 1980, the US CPSC has received reports of more than 700 deaths in spas and hot tubs. Approximately one-third of these were drownings of children under five years of age (CPSC, undated, a).

2.1.2 Near-drowning

As with drowning, near-drowning may be classified as either "wet" or "dry." The difference between drowning and near-drowning is that in a near-drowning, rescue was successful, and death was prevented.

Near-drowning is worthy of special mention, however, because it can result in considerable disability. If submersion was long enough, brain injury, paralysis, respiratory conditions and nervous system trauma can occur. Near-drowning has a detrimental effect on the respiratory system, and, on recovery, the nearly drowned person may experience a build-up of fluid in the lungs. This fluid build-up can lead to pneumonia and, in some cases, a fatal condition called "late" or "secondary" drowning. In late drowning, if water has entered the body, rapid absorption will take place from the stomach into the bloodstream, causing a distortion of the pH balance. Death can occur up to 72 h later. In the case of saltwater immersion, late drowning may also occur from residual water in the lungs drawing fluid from the bloodstream, causing pulmonary oedema or shocked lung syndrome. This may occur many hours after the event.

The disabilities associated with near-drowning generate considerable medical costs in maintenance care. The annual cost of care per year in a chronic care facility for an impaired survivor of a near-drowning event is estimated at approximately $100,000 (Wintemute et al., 1987). It has also been estimated that the lifetime cost for drownings and near-drownings — including productivity losses and losses due to premature death — amounts to about $65,000 per person (Rice et al., 1989).

Opinions differ as to how long the brain can be deprived of oxygen before permanent disabilities occur. DeNicola et al. (1997) suggest that submersions longer than 10 min, lack of cardiopulmonary resuscitation (CPR) at the scene or the need for more than 20 min of resuscitation lead to a poor prognosis. Other statistics from the USA (Spyker, 1985; American Academy of Pediatrics, 1993) suggest that:

- For every child who drowns, four children are hospitalized for near-drowning.
- One-third of near-drowning paediatric victims who are comatose on admission to the hospital will suffer significant neurological damage.
- Irreversible brain damage may occur in 3–5 min.

2.1.3 Contributory factors

Data suggest that males are more likely to drown than females. Males are associated with higher exposure to the aquatic environment (through both occupational and recreational uses) and a higher consumption of alcohol, leading to decreased ability to cope, impaired judgement and greater bravado (Dietz & Baker, 1974; Mackie, 1978; Plueckhahn, 1979; Nichter & Everett, 1989; Quan et al., 1989; Howland et al., 1996). Alcohol consumption is one of the most frequently reported contributory factors associated with drownings and near-drownings in adults. Among children, lapses in parental supervision are the most frequently cited contributory factor (see, for example, Quan et al., 1989). Private pools (including ornamental, swimming and paddling pools) contribute significantly to drowning statistics, especially in children.

While a high proportion of persons drowning are non-swimmers or poor swimmers — as many as two-thirds, according to Spyker (1985) — there are conflicting opinions as to the role of swimming skills in preventing drowning and near-drowning (Patetta & Biddinger, 1988; Asher et al., 1995). Hyperventilation before breath-hold swimming and diving has been associated with a number of drownings among individuals, almost exclusively males, with excellent swimming skills; the manoeuvre, which makes it possible for a person to extend his time under water, can cause loss of consciousness due to hypoxia (Craig, 1976; Spyker, 1985). Attempted rescue also represents a significant risk to the rescuer; Patetta & Biddinger (1988), for example, report the death by drowning of the would-be rescuer in a significant number of cases.

Inlets and outlets where the suction is extremely strong can entrap body parts or hair, causing the victim’s head to be held under water. Most accidents involve people with shoulder-length or longer hair. Hair entrapment occurs when the water flow into the inlet takes the bather’s hair into and around the outlet cover, and the hair is pulled into the drain as a result of the suction created. Since 1978, the CPSC has received reports of 49 incidents, including 13 deaths, of hair entanglement in spas, hot tubs or whirlpools in the USA (CPSC, undated, a). This suction problem may also occur in the main pool drains of swimming pools, but to a much lesser extent than with spas and hot tubs.

A number of drowning deaths have also occurred after the body or a limb has been held against a drain by the suction of the circulation pump. This may occur in a spa, swimming pool or wading pool. The US CPSC has received reports of 18 incidents of body part entrapment (including five deaths) since 1980 (CPSC, undated, a). Young children, typically between the ages of 8 and 16 years, are particularly likely to play with open drains, inserting hands or feet into the pipe and then becoming trapped with the resulting suction. Any open drain or flat grating that the body can cover completely, combined with a plumbing layout that allows a build-up of suction if the drain is blocked, presents this hazard.

High temperatures (above 40 °C) in spas or hot tubs may cause drowsiness, which may lead to unconsciousness and, subsequently, drowning (see section 2.7).

Further contributory factors in drowning and near-drowning include those related to the bather, such as pre-existing health condition; those related to the staff, such as lack of proper training for emergency response; and those related to the pool facility, such as water depth, water clarity, pool configuration and pool size. Water clarity is particularly critical to water safety, in several ways. If it is not possible to see the bottom of the pool at its deepest point, lifeguards may not be able to identify persons in distress. In addition, a person entering the pool may not be able to see another person under the water or may not be able to judge the pool bottom configuration.

2.1.4 Preventive actions

Since systematic information on the factors involved in drowning or near-drowning incidents is lacking, few preventive measures have been evaluated. Expert opinion suggests that warnings displayed in clear and concise signage (e.g., pictographs) and text in the prevailing language of facility users are an important preventive action. Water safety instruction and adult supervision of children also have value as preventive actions. However, lapses in supervision make this an insufficient measure alone (Quan et al., 1989). The effectiveness of swimming instruction at different ages for the prevention of child drowning has not been determined, although one report suggests that swimming instruction is effective at improving swimming ability, pool safety behaviour and recovery from a simulated fall in the pool (Asher et al., 1995).

For outdoor pools, care must be taken to prevent illicit entry. Barriers such as fences or walls may not prevent drowning but may delay or prevent a child from entering a swimming pool area unsupervised. Installation of isolation fencing around outdoor pools, which separates the pool from the remaining yard and house, has been shown by some studies to decrease the number of pool immersion injuries by more than 50% (Pearn & Nixon, 1977; Milliner et al., 1980; Present, 1987). In Australia, however, advocacy to promote legislation for isolation fencing around pools failed to achieve its aim of mandatory fencing (Carey et al., 1994). A study by Logan et al. (1994) reports that 76% of residential pools in the USA are adequately fenced; it also suggests that if this proportion were increased to 100%, most drownings among children under five years of age in a pool would still not be prevented. Pool alarms and pool covers have not been shown to be reliable preventive measures for very young children. In fact, pool covers may themselves contribute to drowning — if they are not strong enough to hold the child’s weight, the child could slip under the cover and be trapped by it, or the child could drown in small puddles of water formed on their surface.

For spas and hot tubs, safety precautions that can be taken to prevent drowning and near-drowning include the use of locked safety covers, dual drains and drain covers, and an accessible cut-off switch for the pump (CPSC, undated, a).

The principal contributory factors and preventive actions concerned with drowning and near-drowning are summarized in Table 2.2.

Table 2.2: Drowning and near-drowning: principal contributory factors and preventive actions

Contributory factors	Preventive actions
➢ Swimming in deep water ➢ Drain suction excessive ➢ Falling unexpectedly into water ➢ Not being able to swim ➢ Breath-hold swimming and diving ➢ Alcohol consumption ➢ High water temperatures ➢ Easy illicit access to pools ➢ Inadequate pool and spa covers	➢ Teaching not to swim beyond skill level ➢ Teaching to stay away from water ➢ Parental/caregiver supervision of children ➢ Diving only under suitable conditions ➢ Education/public awareness ➢ Suction outlet cannot be sealed by single person, and at least two suction outlets per pump ➢ Accessible emergency shut-off for pump ➢ Grills/pipes on drain gates preclude hair entrapment ➢ Wearing bathing caps ➢ Maintaining water temperature in hot tubs and spas below 40 °C ➢ Isolation fences around outdoor pools, and locked doors for indoor pools ➢ Locked safety covers for spas and hot tubs

2.2 Spinal injury

Few estimates of spinal injury incidence or prevalence are available. Stover & Fine (1987) estimated the total prevalence of spinal cord injury in the USA to be around 906 per million, with an annual rate of incidence of around 30 new spinal cord injuries per million persons at risk.

Blanksby et al. (1997) reviewed data from a series of studies regarding diving accidents as the cause of acute spinal injury in various regions of the world. In one study (Steinbruck & Paeslack, 1980), 212 of 2587 spinal cord injuries were sports related, 139 of which were associated with water sports, the majority (62%) with diving. Diving-related injuries were found to be responsible for between 3.8% and 14% of traumatic spinal cord injuries in a comparison of French, Australian, English and American studies (Minaire et al., 1983), for 2.3% in a South African study and for 21% in a Polish study (Blanksby et al., 1997).

In diving incidents of all types, injuries are almost exclusively located in the cervical vertebrae (Minaire et al., 1983; Blanksby et al., 1997). Statistics such as those cited above therefore underestimate the importance of these injuries, which typically cause quadriplegia or paraplegia. In Australia, for example, diving incidents account for approximately 20% of all cases of quadriplegia (Hill, 1984). The financial cost of these injuries to society is high, because persons affected are frequently healthy young persons, typically males under 25 years of age (DeVivo & Sekar, 1997).

2.2.1 Contributory factors

Data from the USA suggest that diving into the upslope of a pool bottom or shallow water is the most common cause of spinal injuries in pools. Diving from trees, balconies and other structures is particularly dangerous, as are special dives such as the swan or swallow dive, because the arms are not outstretched above the head but are to the side of the body (Steinbruck & Paeslack, 1980). Familiarity with the water is not necessarily protective; in one study from South Africa (Mennen, 1981), it was noted that the typical injurious dive is into a water body known to the individual.

Minimum depths for safe diving are greater than is frequently perceived, but the role played by water depth has been debated. Inexperienced or unskilled divers require greater depths for safe diving. The velocities reached from ordinary dives are such that the sight of the bottom, even in clear water, may provide an inadequate time for deceleration response (Yanai et al., 1996).

Most diving injuries occur in relatively shallow water (1.5 m or less) and few in very shallow water (i.e., less than 0.6 m), where the hazard may be more obvious (Gabrielsen, 1988; Branche et al., 1991). In a sample of 341 persons with spinal injuries resulting from swimming pool incidents, over half of the injuries occurred when the individuals dived into less than 1.2 m of water (DeVivo & Sekar, 1997).

Alcohol consumption may contribute significantly to the frequency of injury, through diminished mental faculties and poor judgement (Howland et al., 1996; Blanksby et al., 1997). Young males appear to be more likely to experience this adverse health outcome; in the study by DeVivo & Sekar (1997), 86% of the 341 persons with spinal injuries resulting from swimming pool incidents were men, with an average age of 24 years. The lack of signage may also be a contributory factor. In the same study, almost all the injuries (87%) occurred in private/residential pools; depth indicators were not present in 75% of cases, and there were no warning signs in 87% of cases (DeVivo & Sekar, 1997).

A proportion of spinal injuries will lead to death by drowning. While data on this are scarce, it does not appear to be common (see, for example, Bartram et al., 2000). In other cases, the act of rescue from drowning may give rise to spinal cord trauma after the initial impact (Mennen, 1981; Blanksby et al., 1997) because of the rescue technique. However, there is no evidence that impact upon the water surface gives rise to serious spinal injury (Steinbruck & Paeslack, 1980).

2.2.2 Preventive actions

The principal contributory factors and preventive actions for spinal cord injuries are summarized in Table 2.3. Evidence suggests that technique and education are important in injury prevention (Perrine et al., 1994; Blanksby et al., 1997), and preventive programmes can be effective. In Ontario, for example, the establishment of preventive programmes by Sportsmart Canada and widespread education decreased the incidence of water-related injuries substantially between 1989 and 1992 (Tabor et al., 1993).

Table 2.3: Spinal injury: principal contributory factors and preventive actions

Contributory factors	Preventive actions
➢ Diving: • Into a shallow pool • Into a pool of unknown depth ➢ Improper diving ➢ Jumping into water from	➢ Local hazard warnings ➢ General public (user) awareness of depth hazards and safe behaviours ➢ Early education in diving hazards and safe behaviours ➢ Lifeguard supervision

Contributory factors	Preventive actions
trees/balconies/other structures ➢ Poor underwater visibility	➢ Access to emergency services ➢ Diving instruction ➢ Poolside wall markings

Because of the young age of many injured persons, awareness raising and education regarding safe behaviours are required early in life. Many countries have school-age swimming instruction that may inadequately stress safe diving, but which may provide a forum for increased public safety (Damjan & Turk, 1995). Education and awareness raising appear to offer the most potential for diving injury prevention, in part because people have been found to take little notice of posted signs and regulations (Hill, 1984).

2.3 Brain and head injury

Impact on the skull and injuries to the head, including scalp, facial abrasions and breaks, have been associated with swimming pools and spas and have resulted in permanent neurological disability, as well as disfigurement. The contributory factors and preventive actions associated with brain and head injuries include those for spinal injuries as well as those for limb and minor impact injuries and are summarized in Tables 2.3 and 2.4 (see below).

2.4 Retinal dislocation

Retinal detachment can also occur from collisions in the water, impacting the water with incorrect entry and hitting hard objects. The contributory factors and preventive actions associated with retinal dislocation are similar to those for spinal injuries, summarized in Table 2.3, with the addition of avoidance of collisions between those jumping or diving into the pool and those already in it. This may involve segregation of use and education of users.

2.5 Fractures, dislocations and abrasions

Arm, hand, leg and foot/toe injuries have occurred from a variety of activities in pools and their immediate surroundings. Expert opinion suggests that these incidents are common and generally go unreported.

Slippery decks, uneven pavements, uncovered drains and exposed pool spouts may cause injuries to pool users. Reckless water entries, such as jumping onto others in swimming pools, jumping into shallow water and running on decks, may also result in injury. Slip, trip and fall accidents may be the result of swimming aids, such as rings, floats, etc., left poolside in leisure pools.

Maintenance of surfaces, supervision of pool users, providing appropriate warnings, improved pool design and construction, ensuring good underwater visibility and pool safety education are among the actions that can reduce these numerous and often unreported incidents. Table 2.4 provides examples of some of the factors that contribute to limb and minor impact injuries and preventive actions.

Table 2.4: Limb and minor impact injuries: principal contributory factors and preventive actions

Contributory factors	Preventive actions
➢ Diving or jumping into shallow water	➢ General user awareness of hazards and safe behaviours

Contributory factors	Preventive actions
➢ Overcrowded pool ➢ Underwater objects (e.g., ladders) ➢ Poor underwater visibility ➢ Slippery decks ➢ Swimming aids left poolside	➢ Appropriate surface type selection ➢ Limits on bather load

2.6 Disembowelment

In addition to hair and body entrapment resulting in drowning, there have been a few reports of incidents in which the suction from the pool or spa drain has pulled intestines out of the body. Fifteen incidents of evisceration/disembowelment were reported to the US CPSC between 1980 and 1996, for example (CPSC, undated, b). The suction drain gate in old swimming pools, spas and hot tubs can become brittle and crack, or the grate over the drain may become loose or missing. If a person stands or sits on a broken or missing grate, the resulting suction force can cause disembowelment. This is a particular hazard for young children in shallow pools.

Mitigating measures are similar to those against entrapment leading to drowning (see Table 2.2). It is uncertain if reduced vacuum — for example, through multiple outlets — is as effective against disembowelment injuries as it is against drowning, since these occur almost immediately at a small pressure differential.

2.7 Hazards associated with temperature extremes

Body overheating can occur in spas and hot tubs, where water temperatures may be above 40 °C. High temperatures can cause drowsiness, which may lead to unconsciousness, resulting in drowning. In addition, high temperatures can lead to heat stroke and death (CPSC, undated, a). The US CPSC has received reports of several deaths from extremely hot water (approximately 43 °C) in spas (CPSC, undated, a).

Plunge pools present similar problems, but at the other temperature extreme. These small, deep pools generally contain water at a temperature of 8–10 °C and are used in conjunction with saunas or steam baths. Adverse health outcomes that may result from the intense and sudden changes in temperature associated with the use of these pools include slowed heart beat, hypothermia, impaired coordination, loss of control of breathing, muscle cramps and loss of consciousness.

In general, exposure to temperature extremes should be avoided by pregnant women, users with medical problems and young children, and prolonged immersion in spas or other pools with high or low temperatures should be avoided or approached with caution.

Educational signage and displays, warnings from pool staff and regulations on time limits for exposure and medical preconditions are some examples of preventive actions for hazards associated with temperature extremes (see Table 2.5). Further information on this subject is given in Volume 1 of the *Guidelines for Safe Recreational-water Environments.*

Table 2.5: Hazards associated with temperature extremes: principal contributory factors and preventive actions

Contributory factors	Preventive actions
➢ Cold plunge when not conditioned	➢ Gradual immersion with supervision

Contributory factors	Preventive actions
➢ Prolonged immersion in hot water	➢ Medical recommendations for pregnant women, people with medical conditions

2.8 Hazards associated with “feature pools”

Many pools contain a number of features that present their own particular requirements to ensure safe use. Water slides add excitement but may present physical hazards, particularly where riders go down in pairs, too close to each other or headfirst; or where riders stop, slow down or stand up on the slide. Failure to leave the pool area immediately after arriving from the slide may also present physical hazards.

Wave machines may also cause a higher level of excitement and increased bather load, and extra vigilance is needed by lifeguards and bathers alike. The possibility exists for entrapment of limbs in wave machine chambers; therefore, all parts of the wave machine should be enclosed by a guard. Design issues, user awareness and education are important considerations in feature pools.

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