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Home Swimming Pool Design to Improve Diving Safety

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This study sought to establish home swimming pool design guidelines to minimize risk of diving injury. Using a qualitative design, interviews with representatives of home pool companies were analyzed and common themes were determined. Pool company display centers and advertising materials were also examined. The typical in-ground fiberglass home pool was described by manufacturers as 8 m in length, with a constant gradient of 0.9 m to 1.8–2.0 m deep. Comparisons between this profile and the underwater pathways of young adults in previous studies by the authors showed that if the dives had been performed in this typical pool, impact would have occurred for some dives. Safety features such as depth markings and signage were absent from all pools. We concluded that recreational swimmers with limited diving skills are at risk of diving injury in the typical home swimming pool. Recommendations are provided of strategies that can be implemented by home pool owners to improve pool safety.

Shallow water diving injury is a significant cause of traumatic spinal injury throughout the world, and the need to address this issue has long been highlighted in spinal cord injury literature (Bailes, Herman, Quigley, Cerullo, & Meyer, 1990; Barss, Hind, Ledus, Lepage, & Dionne, 2008; Blanksby, Wearne, & Elliott, 1996; Damjan & Turk, 1995; DeVivo & Sekar, 1997; Frankel, Montero, & Penny, 1980; Gaspar & Silva, 1980; Kraus, Franti, Riggins, Richards, & Borhani, 1975; Laughery, Young, & Rowe, 1992; Scher, 1992; Torg, 1985, 1991; Torg, Wiesel, & Rothman, 1982). From July 2005 to June 2006, the age-adjusted incidence rate of traumatic spinal injury in the Australian population age 15 years and older was 15.7 new cases per million population (95% CI 13.8–17.6; Cripps, 2007). Water related spinal cord injury contributed 9% of this total, but the nature of diving injuries means that about 95% of these result in cervical injury (Cripps, 2006). Accordingly, these injuries make up 14–20% of Australian tetraplegia injuries each year.

Throughout the world, diving injuries occur predominantly among adolescent and young adult males (Aito, D'Andrea, & Werhagen, 2005; DeMers, 1994; Young, Burns, Bowen, & McCutchen, 1982) and typically the injury results in tetraplegia (Biering-Sorensen, Pedersen, & Clausen, 1990). While limited infor-

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mation has been published regarding the specific locations of diving spinal cord injury incidents, home pools are known sites of such injury. In 2005–2006, 24% of water related spinal injuries in Australia occurred in swimming pools (Cripps, 2007). In Quebec, Canada, over the period 1961–2004, 49% of diving spinal injuries occurred in swimming pools (Barss et al., 2008). Other North American studies report the contribution of swimming pool incidents to overall aquatic spinal cord injuries as 28.2% (Bailes et al., 1990), 45% (Tator & Palm, 1981), and 77.5% (Kluger, Jarosz, Paul, Townsend, & Diamond, 1994), while a British study found that 32% of aquatic spinal cord injuries were sustained in swimming pools (Frankel et al., 1980).

A series of studies by the authors followed Green and Kreuter's (1991) Precede-Proceed Model of Health Promotion and Planning to investigate ways to minimize diving related spinal injury. First, risk factors were studied during commonly used head first entries by 95 young adult recreational swimmers. Dives were video-recorded and analyzed to determine characteristics that distinguished "high risk" dives from those of low risk, as indicated by dive depth and distance at maximum depth (Blitvich, McElroy, Blanksby, & Douglas, 1999). An intervention program followed for 34 of the initial study participants who were identified as having low diving skills. Simple diving skills were taught over seven,10-min sessions after which dive entries were again video-recorded to measure any changes to the levels of skill and risk of participants' dives (Blitvich, McElroy, & Blanksby, 2000). Significant improvement in diving skill and safety was evident and these improved skills were retained after periods of eight and 20 months without further practice (Blitvich, McElroy, & Blanksby, 2003; Blitvich, McElroy, Blanksby, & Parker, 2003). Additional evidence of the protective role of skill in the performance of safer diving was illustrated in a further investigation of skilled competitive swimmers who dived into deep (2 m) and shallow (1.2 m) water and demonstrated they could modify their dive depths without performance decrement (Blitvich, McElroy, Blanksby, Clothier, & Pearson, 2000).

The findings of this series of studies revealed that minimal, targeted training could significantly decrease the risk of a potentially dangerous activity. Increased awareness and improved diving skills can influence some behavioral factors involved in diving injuries; however, given the catastrophic consequences of shallow water diving spinal cord injury, investigation of engineering strategies for the prevention of diving injury is warranted.

Objective

The current study considers engineering and design factors that can contribute to diving risk and recommends some preventive measures. It investigates trends in home swimming pool design and client reasons for installing pools in Western Australia (WA) as interpreted by swimming pool manufacturers. Using this information, guidelines are outlined for pool design and diving risk minimization. Access to home swimming pools continues to grow. For example, in 2004, WA figures indicated that 35% more new pools were installed than the previous year (personal communication, Reed Construction, September 2005). Currently, despite several published Australian Standards for swimming pools (Standards

Australia International, 2008), there are no guidelines regarding home swimming pool design to minimize diving injury risk. This also appears to be the case internationally.

Method

Participants

This study began in 1999 and was updated and completed in 2008. Representatives from the companies that manufacturer and install more than 80% of home pools in Perth, WA, were interviewed regarding the design characteristics of home swimming pools and client reasons for installing home pools. The purpose of the study was explained to interviewees, advertising materials were collected for scrutiny, and visits were made to company display centers to examine display pools. In WA, approximately 65% of home pools are fiberglass, 25–30% concrete, and the remainder are vinyl liner pools (B. Price, personal communication, July 2008). To ensure representative coverage of home pool manufacturers, the Swimming Pool and Spa Association—WA (SPASA WA) was approached and agreed to provide the names of the three largest fiberglass home swimming pool companies and the two largest concrete pool manufacturers who collectively install in excess of 80% of all WA home pools (B. Price, personal communication, January 1999). Two of the fiberglass pool companies also construct a small number of concrete pools.

Procedures

Interviews. The fiberglass pool company interviews were conducted at each company display center. Each interview followed the same format of a series of open-ended questions. Telephone interviews were conducted for concrete pool companies, again using the same open-ended questions. Notes were recorded during interviews and data were later analyzed and coded to determine common themes.

Display Pool Inspections. Fiberglass pool display centers had six to 10 pools installed on site, of varying dimensions, styles, and characteristics. Pools were observed and characteristics, such as dimensions (length, depth, shape), color of pool floor, presence (or absence) of depth indicators, and demarcation between deep and shallow water were recorded.

Advertising Material (Including Pool Dimensions). Pool company advertising material was collected for all fiberglass pool manufacturers. Content analysis was conducted and themes were extracted. The dimensions (length, width, and depth) of all fiberglass pools were obtained from company advertising brochures and websites. For fiberglass pools, as the molds are poured off-site and the pool then transported and installed at the client's home, each company has a range of pools from which the client can select. The dimensions of the most commonly installed fiberglass pools were compared with the underwater pathways of dives performed by recreational standard swimmers in an earlier study (Blitvich et al., 1999) to determine the risk of contact with the pool bottom during diving.

Results and Discussion

Reasons for Purchasing a Home Pool

All interviewees listed the most common reason provided by clients for installing a pool was for children to play. Pool installation was popular among families with late primary school aged children (10–12 years). Pool manufacturers noted that some parents wanted their children to use their own home pools rather than visit nearby homes. Manufacturers stated that it was unusual for families with only toddlers to install pools; rather, they waited until children were older. They tended to assume the drowning risk then was diminished.

Another reason for installing a pool was for adult fitness through lap swimming. A third was the aesthetic look in the garden. Swimming pool companies talked of clients who want the pool to be part of a "total concept" for the home and garden.

The intended use of a pool influences the shape clients select. When installing a pool for children's play or adult fitness, a rectangular shape is usually selected to maximize playing space. Older people tend to choose curved or kidney shaped pools for appearance and landscaping.

Typical Pool Dimensions

Fiberglass Pools. Pools from the three largest WA fiberglass pool companies ranged in length from 5–10.65 m. The most common length was 8 m and depth ranges were from 0.9 m to 1.8–2.0 m. All fiberglass pools have a constant gradient from the shallow to the deep end. One manufacturer observed a recent trend toward slightly shorter pools because of smaller building blocks and increased house-to-plot ratios. Fiberglass pool choices are limited to the range provided by a manufacturer, based on the company's pool molds.

Concrete Pools. One reason cited for choosing a concrete pool over fiberglass was design flexibility. This is especially important when the site has access or space restrictions that make installation of a fiberglass pool difficult or impossible. Concrete is preferred for pools larger than those available in fiberglass, such as when designed primarily for lap swimming. Most concrete pools are 8–10 m long, but one manufacturer had constructed an 18 m and a 25 m pool in the previous 12 months. While concrete pools are individual in design, one manufacturer noted that a typical concrete pool was 9 m long with a flat area of 2 m in the 1 m deep shallow-end, a 5 m slope between deep and shallow, and a flat area of 2 m in a 2 m deep-end (see Figure 1).

Concrete pools are more expensive than fiberglass, but cost difference narrows as pool length increases. The cost for a 7 m concrete pool is about 40% more than fiberglass, while a 10 m concrete pool is only about 20% more expensive than fiberglass. Concrete pools are usually at least 7 m long as purchasers deem the extra cost of concrete too great for pools shorter than this.

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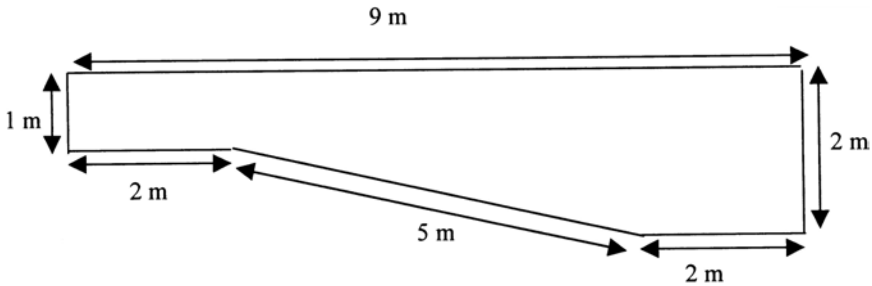

Figure 1 — Typical concrete home pool.

Clients consider the ability to design their own pools an advantage of concrete pools. Design flexibility means practically any size and shape is possible. It should be noted that a regular, rectangular shape can make recognition of deep and shallow areas easier. This could be important for visiting pool users but none of the manufacturers highlighted this factor.

Diving

While advertising literature from two manufacturers included photographs of people diving, four of the five pool manufacturers stated that they actively discouraged diving into home pools if mentioned by clients. The spokesperson from the company that did not discourage diving said that if mention was made of diving, he visited the site and encouraged placement of the pool with a maximum of 1–1.5 m approach to restrict the opportunity for running dives. This spokesperson considered 1.5 m was a reasonable depth into which children could dive, but the Royal Life Saving Society of Australia requires a minimum depth of 1.8 m for recreational diving in public pools (RLSSA, 2001).

A small number of clients wanted the opportunity to dive into their home pools. For this situation, the four companies that construct concrete pools all recommended deep pools. One stated that if clients planned to install a diving board, he insisted on a deep-end minimum depth of 3.5 m. Another encouraged such clients to design a pool with a "less radical shape" to increase safety and cautioned clients against diving from heights such as rock waterfalls or nearby balconies. When asked how they would react if a client wanted a pool with only a short distance between the deep and shallow areas, the manufacturers said they would convince the client to modify the plan to minimize the risk of a diving injury against the steep upslope.

As the concrete pool companies construct pools that may have been client designed, they were asked whether guidelines regarding depth changes and slope gradients, specifically devised to minimize the risk of diving injury, would be valuable. The contrasting responses were interesting as one spokesperson believed that guidelines, with a disclaimer, would be "fantastic." He thought all concrete pool manufacturers would be interested and that the guidelines could be promoted by SPASA. However, another was extremely negative, stating that people should be able to build whatever they want without any restriction. He opposed isolation

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fencing of home pools and considered any further guidelines would be unnecessary.

Other Safety Factors

The shape of both the deep area and the whole pool can influence diving safety. Figure 2 demonstrates increased risk in designs where the deep end is short, compared with an extended deep area, while Figure 3 shows how an irregular pool shape can decrease the area available for safe diving (Laughery et al., 1992).

No pool manufacturers included depth indicators and their absence is considered a contributing factor in diving injury (Laughery et al., 1992; Torg, 1991). Depth indicators, plus symbols and warning texts, are required in public pools for shallow water (RLSSA, 2001). Their inclusion in home pools would improve safety for visitors using the pool for the first time. Markings on the pool bottom would provide users with a reference that could assist in depth perception (Gabrielsen, 1980), but no pools were found that included any such markings.

Swimming pools are available in a range of colors. When observing display pools of the same depth but of different color, it was clear that color choice influenced the perceived depth. Light colored pools appeared shallower than darker colors. Selecting the lightest color available for fiberglass pools or white tiles or paint for concrete pools provides users with the preferred environment for esti-

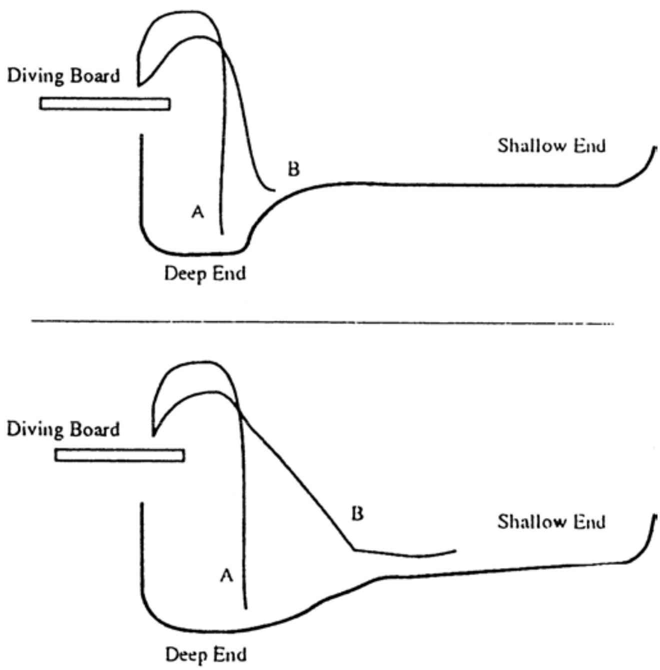

Figure 2 — Different deep end configurations (from Laughery et al., 1992). Reprinted with permission.

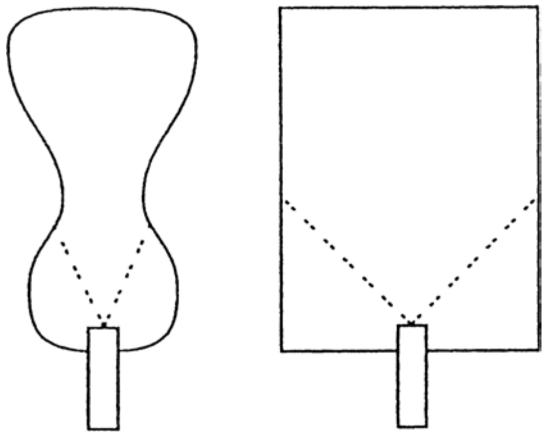

Figure 3 — Different pool shapes (from Laughery et al., 1992). Reprinted with permission.

mating depth. White tiles or paint still appear as a light blue color when viewed through water.

Lighting in the pool surrounds and underwater is important for night use. Inadequate illumination could cause pool users to inaccurately estimate depth and dive too deeply for the water depth (Gabrielsen, 1980).

Water clarity is paramount in assisting pool users to gauge water depth. Decreased clarity reduces the ability to accurately estimate depth and home pool owners must maintain high levels of water quality (Laughery et al., 1992).

Wiklund, Harris, and Loring (1989) wrote that sometimes, unsafe diving behavior can be modified by including warning and “No Diving” signs. Laughery et al. (1992) and Gabrielsen (1980) supported this claim. To minimize the risk of diving injuries, home pool owners should install “No Diving” signs and symbols, plus “Shallow Water” text, when depth is inadequate for diving.

Clear demarcation between deep and shallow water could also help pool users decide which areas are safe for diving and which are not. Laughery et al. (1992) describe a “safety line” rope on the water surface to divide the shallow and deep ends. Similarly, a painted line on the pool bottom could help.

Furniture placement, landscape features such as rock walls, and pool location in relation to other buildings could also be risk factors. Only one pool manufacturer stated that the company he represented discussed this safety aspect with clients. Careful planning should minimize opportunities to use furniture and landscape features as “diving platforms” and render the pool safer.

Pool Design and Diving Safety

Although a variety of fiberglass pool designs are available, manufacturers describe the typical home pool as 8 m in length, 0.9 m to 1.8–2.0 m deep with a constant gradient. Comparisons were made of the maximum depth and distance from the edge of the pool at maximum depth reached during the underwater pathways of dives by young adults in previous studies by the authors (Blitvich et al., 1999).

These were transposed to the dimensions of typical home pools. For this comparison, it was important to consider the extreme measures, rather than mean results, as the deepest or longest dives are those which result in injury.

Four types of dive entries were examined: a dive from deck level to treadwater (treadwater is the characteristic dive for spinal cord injury, where the diver is entering the water to "play"); a dive from deck level to swim a lap (deck); a dive from a standard starting block height of 0.75 m to swim a lap (block); and, for those participants who felt comfortable, a running dive entry (running). Figure 4 represents underwater pathways of the deepest dive observed for each entry condition, superimposed on the profile of a typical 8 m long pool, ranging in depth from 0.9 m to 1.8 m. It clearly demonstrates that if these dives had been performed in this home pool, the treadwater, block, and running dives would have impacted with the pool bottom, potentially resulting in catastrophic injury. The dives in the earlier study by the authors were performed into water with a constant depth of 2 m. It is quite possible that a pool user standing on the edge of a pool would not be able to estimate depth accurately enough to distinguish between 1.8 m and 2.0 m of water. Imprudent behavior, which becomes more likely with consumption of alcohol, further increases the possibility of less controlled, higher risk dives (Perrine, Mundt, & Weiner, 1994).

The swimming pool used for data collection in the earlier studies had deck level water entry, but home pools generally have a lip of approximately 0.08 m. Any increase in take-off height further increases the risk level of the dive. While results of the study of competitive swimmers (Blitvich, McElroy, Blanksby, Clothier et al., 2000) showed that skilled divers can modify dive depth when the pool depth is shallower, this ability is likely to be reduced or absent in swimmers with lower skill levels or highly excited novice children competitors. Hence, children diving into a home pool as part of their play activities may be at increased risk of diving injury. Furthermore, if users are unaware of the pool depth, but have observed others diving without incident, they might assume it is safe and dive too deeply for the circumstances and their own skill levels.

Statistically, a normal curve illustrates that only 0.14% of scores usually fall more than three standard deviations above the mean. The depths recorded for the deck, block, and running conditions revealed that one dive in each condition was deeper than three standard deviations above the mean, or 1.1% of deck and block entries, and 2.9% of running dives, respectively (Blitvich et al., 1999). Two dives (2%) were deeper than three standard deviations above the mean in the treadwater condition. Three different participants were represented among these dives. These findings indicated the risks of injury inherent in diving. Home pool owners should discourage diving in pools less than 1.8 m deep, or where this depth is maintained for less than 5.0 m from the edge of the pool. Running dives and dives from above deck level should be banned.

Implications for Injury Prevention

To prevent shallow water diving injuries, a coordinated approach is required. Education is necessary to develop skilled, low risk dives and enhance awareness of injury potential. In particular, inculcating the habit of locking hands together before every dive is vital, as many recreational divers allow the hands to pull back-

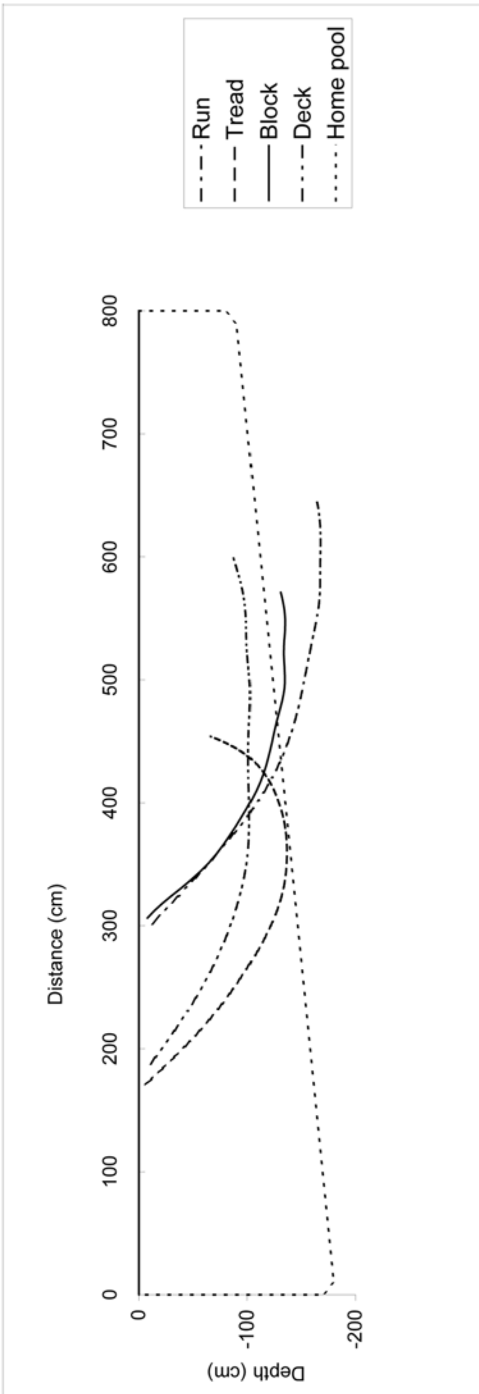

Figure 4 — Deepest dive for each entry condition.

ward before maximum depth, exposing the head and neck to injury upon impact with the upslope (Blitvich, McElroy, & Blanksby, 2000). Engineering and enforcement also play important roles in providing recommendations based upon scientific evidence. The following recommendations result from this study, and from a series of already mentioned diving injury prevention studies published by the authors between 1999 and 2004.

Australian Standards exist for some aspects of swimming pool construction, namely, fencing and gate locks. Perhaps construction regulations also should be established for diving safety and included within a permit system from state/local government bodies for home pool construction. Only pool plans conforming to the regulations would be approved. Government regulation would be preferable, but a fall back option could be industry self-regulation via an appropriate body such as SPASA. For SPASA membership, pool manufacturers would need to demonstrate that all pools they construct adhere to the regulations.

Specific Recommendations

Recommendations for incorporation into swimming pool regulations include the following:

1. Depth indicators. Water depth should be clearly marked so that new pool users can determine water depth before entry. Depth indicators also act as reminders to infrequent users of the venue.
2. "No Diving" signs. It would be prudent for all home pools to have "No Diving" signs and symbols, supplemented by the reason ("Shallow water") in text, as specified by the Australian Standards Association (Standards Australia International, 2002). Pool users should be encouraged to enter the water feet first (e.g., "Feet first is using your head"), to prevent the possibility of injury. While skilled swimmers can perform low risk dives, many home pool users have lower skills. Injury risks increase when large numbers are present and reckless behavior occurs. On such occasions, pool owners would be prudent to implement a "No Diving" policy, especially if alcohol is available. This is important, as experience indicates that alcohol is often involved in water related spinal injury, especially by adolescent and young adult males.
3. Pool bottom markings. Markings on the pool bottom assist pool users to estimate depth. Water can appear deeper when there are no markers on the pool bottom and ends of the pool.
4. Demarcation between deep and shallow water. A clear demarcation between deep and shallow water can assist pool users to quickly assess water depth. Deep water could be indicated by having a different color on the pool bottom for the deep and shallow areas, physical markers such as a series of buoyant floats, or a dark boundary line on the pool bottom between deep and shallow water.
5. Lighting. A minimum standard of lighting should be required to ensure adequate illumination for night time use. One should consider any daytime shadows from nearby structures that could influence perception of water depth by partial or full shadow/sunlight interaction.

6. Water clarity. While pools should include filters that maintain excellent water clarity, some have periods of intermittent, heavy usage. In this circumstance, the filter system must be adequate to accommodate the high load without detriment to water clarity, as decreased water clarity impacts on capacity to determine depth.
7. Landscaping and fencing. Pool surrounds should be planned to minimize run-up length to discourage running dive entries. Positioning of fencing, landscaping, furniture, and other structures should prevent diving. Pool fencing is important to prevent toddlers from entering the pool and drowning and also to emphasize to users that they are entering a recreational area with increased risks and responsibilities.
8. Spinal injury management. Local governments in New South Wales (Australia) mandate that home swimming pools are fenced and that each home pool has a resuscitation poster on the pool fence. Similar requirements for a spinal injury management poster could be implemented. A poster may remind pool users of the severe consequences of diving injuries and be referred to for first aid management in the event of a diving injury. Home pool owners could be required to attend a workshop for training in CPR and spinal injury management.
9. Easy use support board. The development of an easily used support board, to simplify handling suspected spinal injury patients, could be pursued and pool owners encouraged to keep such an aid in the pool area.
10. Diving boards and water slides. The risk of injury is greater when a diving board or water slide is present and extra precautions are required. For pools with a diving board, a diagram of the pool profile, including depths, could be attached to the board. Users of the board would have their attention drawn to water depth before diving. To allow for the diver's increased velocity when using a board, water depth must be increased and deep water maintained for a greater distance. Laughery et al. (1992) outlined the importance of the spring constant and the sprung weight of the board. Guidelines should be provided with respect to these characteristics of a diving board in relation to the pool depth and profile.

These recommendations, when combined with the critical skills aspect ("Lock hands, lock head, steer-up") noted in earlier publications by the authors, are positive steps toward the prevention of diving injuries.

Conclusions

Recreational swimmers with limited diving skills are at risk of sustaining diving injury in the typical home swimming pool. Hence, it is useful to consider the engineering and enforcement processes presented in this paper, along with incorporation of participant education (skills) recommendations of previous research. These provide a comprehensive and multifaceted approach to prevention of diving injuries and enhance safe, enjoyable home pool use.

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