Prevention of spinal cord injuries that occur in swimming pools

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The purpose of this study was to determine the usual circumstances surrounding spinal cord injuries that occur in swimming pools so that appropriate primary prevention programs targeted at high risk persons, activities, and environments could be developed and initiated. A sample of 341 persons enrolled in the National Spinal Cord Injury Statistical Center database since 1973 whose injury was the result of a swimming pool mishap was identified. Medical records were reviewed retrospectively and a survey questionnaire was administered by telephone to 196 persons (57.5%) who were located and agreed to participate. Average age at time of injury was 24 years, 86% of injured persons were men, 95% were white, 70% were never married, 32% had less than a high school education, and only 7% were college graduates. Almost all injuries (87%) occurred in private/residential pools. Most injuries (57%) occurred when diving into less than 4 feet of water, while an additional 38% occurred at water depths between 4 and 8 feet. Depth indicators were not present in 75% of cases. There were no warning signs posted in 87% of cases. There was no lifeguard on duty in 94% of cases. There was self-reported alcohol involvement in 49% of cases, but drugs were involved in only 2% of cases. Almost half of all injuries (46%) occurred during parties. In 44% of cases, the injury occurred during the person's first visit to that particular pool. Ordinary dives accounted for 70% of cases, followed by unusual dives (17%), unintentional pushes (6%), and other circumstances (7%). Almost all injuries (88%) occurred between 1 pm and 1 am with the most frequent time of day being 6 pm, and 82% occurred during June, July or August. Over half (51%) of all injuries occurred on Saturday or Sunday. These results provide important clues to the development of a successful primary prevention program.

Keywords: spinal cord injury; epidemiology; swimming pool; prevention

Introduction

Since 1973, diving mishaps have accounted for 8.5% of spinal cord injuries (SCI) in the United States.¹ This makes diving mishaps the fourth leading cause of SCI in the United States behind only motor vehicle crashes, gunshot wounds, and falls.¹ Diving mishaps are also among the leading causes of SCI in other countries. In decreasing order, diving mishaps have accounted for 23.5% of SCI in Novosibirsk, Russia,² 14% in Brisbane, Australia,³ 11.9% in Toronto, Canada,⁴ 10.5% in Perth, Australia,⁵ 7% in Romania,⁶ 6% in Denmark,⁷ 5.1% in Heidelberg, Germany,⁸ 3.8% in the Rhone-Alpes region of France,⁹ 2.5% in Portugal,¹⁰ but only 1.3% in Japan.^{11,12} Although the percentage of total SCI was not reported, diving mishaps cause 19.8% of all cervical SCI in Poland.¹³

Several previous investigators have documented the demographic and epidemiologic profile of persons who sustain an SCI as a result of a diving mishap.^{5,8,13–23} These injuries almost always occur among males between 15 and 25 years of age. The neurological

level of injury is almost always in the C4–C6 range, and the injury is usually neurologically complete. However, there is a paucity of recent information on the circumstances surrounding these injuries that might lead to the development of effective interventions aimed at their prevention. Therefore, this study was designed to fill that void.

Methods

The National Spinal Cord Injury Statistical Center (NSCISC) database was used to identify possible study subjects. A complete listing of eligibility criteria for enrollment in this database has been published previously.²⁴ The main criteria are that the person must have been treated at a federally designated model regional SCI center since 1973 and that treatment must have occurred within 60 days of injury (within 365 days of injury for persons injured before October 1986). It has been estimated that among all persons in the United States each year who get SCI and survive long enough to be hospitalized, approximately 15% are enrolled in this database.¹ In general, it has been

shown that persons enrolled in this database are representative of all new cases of SCI that occur in the United States each year with the exception that neurologically complete injuries are somewhat over-represented. Nonwhites and males may also be slightly over-represented.¹

The NSCISC database contains information on demographic and injury characteristics of each person, acute care and rehabilitation information and follow-up information that is collected annually. The etiology of injury variable has a code for diving mishaps, but does not distinguish between injuries occurring in swimming pools and natural aquatic environments. Therefore, all persons ($n=1106$) enrolled in the NSCISC database since 1973 by one of the 13 currently active model SCI centers whose injury was the result of a diving mishap and who had not been reported as deceased at the time of their most recent annual follow-up were identified. The medical records of these individuals were reviewed to ascertain whether the injury occurred in a swimming pool. Attempts were then made to contact by phone all persons who were found to have been injured in a swimming pool and all persons for whom the location of injury could not be determined from medical records. A survey questionnaire was then administered by phone to all persons who were successfully contacted, who were injured in swimming pools, and who agreed to participate.

Of the original 1106 diving injuries, 631 (57.1%) occurred in natural aquatic environments, 341 (30.8%) occurred in swimming pools and 134 (12.1%) occurred in unknown locations among persons whose whereabouts were unknown or who could not be contacted by phone. Of the 341 injuries that occurred in swimming pools, 196 (57.5%) completed surveys were obtained. The survey contained 21 questions with possible responses in either a yes/no or multiple choice format and took approximately 10 min to complete. Additional information on the date of injury, as well as demographic and injury characteristics that was already included in the NSCISC database was also used.

Data were analyzed using descriptive statistics such as frequencies and percentages, cross-tabulations, means and standard deviations. To facilitate the interpretation of percentages, although the frequency of unknown responses for each item is listed, these unknown responses were excluded from the calculation of percentages under the assumption that unknown responses would be distributed in the same proportions as those that were known.

Results

Demographic characteristics of the persons who responded to the questionnaire appear in Table 1. Average age at the time of injury was 24 years (median age = 22, range = 11–56), 86% of injured persons were men, 95% were white, 70% were never married, 32% had less than a high school education, and only 7% were college graduates. Over half (53.2%) the injured

persons were employed at the time of injury, 34.4% were students and 11.7% were unemployed. By comparison, when all persons enrolled in the NSCISC database regardless of cause of injury are considered, the mean age at the time of injury is 31, 82% are men, 70% are white, 54% were never married, 59.6% were employed, 18.5% were students, 14.3% were unemployed, 41% have less than a high school education and 8% were college graduates.¹ Therefore, persons whose SCI is the result of a diving mishap are younger, more likely to be white males, less well educated and more likely to never have been married (perhaps because of their younger age) than other persons with SCI.

More injuries occurred in below ground swimming pools (64%) than in above ground swimming pools (36%). Additional circumstances surrounding these injuries appear in Table 2. Almost all injuries (86.7%) occurred in private residential pools. Most injuries (57.2%) occurred when diving into less than 4 feet of water, while an additional 38.0% occurred at water depths between 4 and 8 feet. Depth indicators were not present in 74.9% of cases. There were no warning signs posted in 87.4% of cases. There was no lifeguard

Table 1 Characteristics of persons who sustain spinal cord injuries in swimming pool mishaps

Characteristics	n	%
Gender		
Male	169	86.2
Female	27	13.8
Race/Ethnicity		
White	187	95.4
African-American	6	3.1
Hispanic	2	1.0
Asian	1	0.5
Marital Status		
Single	108	70.1
Married	38	24.7
Divorced	8	5.2
Unknown	42	—
Education Level		
8th grade or less	9	6.0
9th–11th grade	39	26.2
High school graduate	86	57.7
Associate degree	4	2.7
College degree	10	6.7
Masters degree	1	0.7
Unknown	47	—
Occupational Status at Injury		
Employed	82	53.2
Student	53	34.4
Retired	1	0.7
Unemployed	18	11.7
Unknown	42	—
Year of Injury		
1973–1978	12	6.1
1979–1984	57	29.1
1985–1989	70	35.7
1990–1994	57	29.1

on duty in 93.8% of cases. No diving device was used in 76.8% of cases. There was self-reported alcohol involvement in 48.9% of cases, but drugs were

Table 2 Circumstances surrounding spinal cord injuries that occur in swimming pools

<i>Circumstance</i>	<i>n</i>	<i>%</i>
Water depth		
Shallow (0–4 feet)	107	57.2
Intermediate (4.1–8 feet)	71	38.0
Deep (> 8 feet)	9	4.8
Unknown	9	–
Type of warning signs posted		
None	160	87.4
No diving	13	7.1
Shallow water	4	2.2
Other	6	3.3
Unknown	13	–
Understood posted signs		
No	2	1.1
Yes	21	11.5
No signs	160	87.4
Unknown	13	–
Presence of depth indicators		
Not present	128	74.9
Present	43	25.1
Unknown	25	–
Lifeguard on duty		
No	182	93.8
Yes	12	6.2
Unknown	2	–
Daylight status		
Daylight	101	52.1
Twilight (dusk)	21	10.8
Darkness	72	37.1
Dawn	0	0.0
Unknown	2	–
Artificial lighting		
None	94	52.8
Turned off	31	17.4
Turned on/adequate	29	16.3
Turned on/inadequate	24	13.5
Unknown	18	–
Alcohol involvement		
No	95	51.1
Yes	91	48.9
Unknown	10	–
Drug involvement		
No	181	97.8
Yes	4	2.2
Unknown	11	–
Previously dove into this pool		
No	52	27.8
1–5 times	18	9.6
More than 5 times	117	62.6
Unknown	9	–
Diving device		
None	142	76.8
High diving board	3	1.6
Low diving board	16	8.6
Competition blocks	9	4.9
Ladder or steps	8	4.3
Other	7	3.8
Unknown	11	–

involved in only 2.2% of cases. Almost half (46.1%) of all injuries occurred during parties. In fact, other people are virtually always present at the time of the injury (97.4%) perhaps because these injuries would usually result in death unless someone else was there to provide assistance. In 44.0% of cases, the injury occurred during the person's first visit to that particular pool, and in 27.8% of cases, the injury resulted from the person's first dive into that pool. Ordinary dives accounted for 69.7% of injuries, followed by unusual dives (16.8%), unintentional pushes (6.0%) and other circumstances (7.0%). Only one injury (0.5%) was caused intentionally.

Almost all injuries (88%) occurred between 1 pm and 1 am with the most frequent time of day being 6 pm (Figure 1). Over half (52.1%) of all injuries occurred during daylight hours, while 10.8% occurred during twilight (dusk) and 37.1% occurred in darkness (Table 2). Artificial lighting was generally not present (52.8%) or turned off (17.4%). When artificial lighting was turned on, it was inadequate for the situation ($n=24$) almost as often as it was adequate ($n=29$) (Table 2).

Almost all injuries (82%) occurred during the summer months of June, July and August when outdoor temperatures are warmer and daylight lasts longer (Figure 2). In contrast, when all spinal cord injuries in the NSCISC database regardless of cause are considered, only 33% occurred during these 3 months.¹

Over half (51%) of SCI resulting from diving mishaps occurred on Saturday or Sunday, with an

Table 2 *Continued*

<i>Circumstance</i>	<i>n</i>	<i>%</i>
Intentionality		
Pushed (intent to harm)	1	0.5
Pushed (unintentional/play)	11	6.0
Ordinary dive	129	69.7
Unusual dive	31	16.8
Other	13	7.0
Unknown	11	–
Pool Ownership		
Public	16	8.2
Country/Swimming club	8	4.1
Private/residential	169	86.7
Other	2	1.0
Unknown	1	–
Pool Familiarity		
Own pool	14	7.3
First visit	85	44.0
Second visit	8	4.1
Third or more visit	86	44.6
Unknown	3	–
Party		
No	104	53.9
Yes	89	46.1
Unknown	3	–
Other persons present		
No	5	2.6
Yes	191	97.4

additional 14% on Friday (Figure 3). By comparison, only 38.6% of all injuries regardless of cause that are included in the NSCISC database occurred on Saturday or Sunday.¹

The consequences of SCI resulting from diving mishaps appear in Table 3. All injuries were in the cervical region of the spine, with 50.5% resulting in

neurologically complete tetraplegia at the time of discharge from rehabilitation. Injury at the C5 level was most common (35.1%), followed by C6 (26.8%) and C4 (17.0%). Only 3.9% were discharged as ventilator-dependent. Unlike motor vehicle crashes and other causes of SCI, other associated injuries such as head injuries, nonvertebral broken bones and

Figure 1 Occurrence of SCI in swimming pools by time of day

Figure 2 Occurrence of SCI in swimming pools by month

Figure 3 Occurrence of SCI in swimming pools by day of week

Table 3 Consequences of spinal cord injuries that occur in swimming pools

Consequence	n	%
Injury level at discharge		
C1	2	1.0
C2	1	0.5
C3	6	3.1
C4	33	17.0
C5	68	35.1
C6	52	26.8
C7	24	12.4
C8	6	3.1
Recovered	2	1.0
Injury completeness at discharge		
Complete	99	55.0
Incomplete-sensory sparing	36	20.0
Incomplete-motor nonfunctional	13	7.2
Incomplete-motor functional	30	16.7
Recovered	2	1.1
Unknown	16	—
Ventilator-dependent at discharge		
No	148	96.1
Yes	6	3.9
Unknown	42	—
Non-vertebral fracture		
No	150	98.0
Yes	3	2.0
Unknown	43	—
Head injury		
No	66	97.1
Yes	2	2.9
Unknown	128	—
Loss of consciousness		
No	137	90.7
Yes	14	9.3
Unknown	45	—
Pneumothorax		
No	69	95.8
Yes	3	4.2
Unknown	124	—
Place of residence at discharge		
Private home	149	97.4
Other hospital/nursing home	2	1.3
Group living/other	2	1.3
Unknown	43	—
Sponsor of care		
Private insurance	110	67.9
Medicaid	36	22.2
Department of vocational rehabilitation	11	6.8
Workers Compensation	2	1.2
Medicare	1	0.6
Indigent	2	1.2
Unknown	34	—

traumatic pneumothorax were infrequent occurrences among persons injured in diving mishaps.

Average inpatient length of stay for initial acute care and rehabilitation was 141 days (± 77 days), while the average hospital charges for acute care and rehabilitation in 1994 dollars were \$192,414 ($\pm \$151,686$). Although most persons (67.9%) had private health insurance to cover these expenses, many other persons rely on public funding programs such as Medicaid (22.2%) and state departments of vocational rehabilitation (6.8%). Almost all persons were discharged from rehabilitation to a private residence in the community, with only one person being discharged to a nursing home and only one person being discharged to another hospital.

Discussion

The mechanism of SCI resulting from diving into water has been a subject of debate in the literature. The usual type of injury found in most studies appears to result from compression, suggesting that injuries occur when the person's head hits the bottom of the pool.^{13,14,17,25} However, Kewalramani *et al* found diving injuries resulted in only 20% burst fractures and 80% wedge or teardrop fractures, indicating flexion type injuries that they believe occur on impact with the water rather than the bottom of the pool.^{18,19} In the current study, information on the mechanism of injury was not collected. This issue requires further study, because identification of the most appropriate prevention strategies depends in part on knowing exactly how these injuries occur.

The circumstances surrounding spinal cord injuries occurring in swimming pools do not appear to have changed during the past two decades. In a study of injuries occurring prior to 1976, Green *et al* found that 72% of spinal cord injuries occurring in swimming pools took place in shallow water (less than 5 feet).²² Moreover, depth indicators were not present in 49% of cases, no person responsible for the pool area was present in 75% of cases, 64% of injured persons had little or no familiarity with that particular pool, there were no warning signs in 63% of cases, and only 18% of cases involved the use of a diving board.²² All of these findings are relatively consistent with those of the current study.

These results provide important clues to the development of a successful primary prevention program for spinal cord injuries that occur in swimming pools. The most appropriate target population for such a program would appear to be younger aged white males with high school education or less who quite often are still students. These demographic findings are consistent with several other studies of SCI resulting from diving mishaps.^{14,16,18,22}

Educational interventions might be coordinated with local school systems to increase awareness of the potential risks and safety precautions to minimize

those risks. The educational message might focus on becoming familiar with the pool and making sure the depth of the pool is known before diving, avoiding alcohol when using swimming pools, not using pools during darkness, teaching proper diving technique, being careful about trying unusual types of dives, and not using the pool alone. The consequences of SCI resulting from diving mishaps could also be part of the education message.

Pool owners also have a responsibility to provide the safest possible environment for persons who use the pool. Educational programs for pool owners should focus on the need for adequate fencing to keep people away from the pool at inappropriate hours, providing adequate lighting during hours when the pool is to be used, having adequately trained supervision or a lifeguard present, particularly during parties, and having visible and understandable depth indicators located strategically around the pool.

Additional prevention strategies were outlined by Kewalramani and Kraus 20 years ago.¹⁸ These ideas included softening the bottom of swimming pools, muscle strengthening exercises to reduce susceptibility to injury and training in techniques to prevent aggravation of existing spinal cord damage during drowning rescue procedures. Reducing the height of diving boards was also suggested;¹⁸ however, this latter strategy may be less effective than others because only 1.6% of injuries in the current study and 6.9% of injuries reported by Green *et al*²² involved the high diving board.

Several limitations of this study should be noted. First, because this is a study requiring a phone interview several years after the injury occurred, some bias in the identification of the target population for future prevention programs might have occurred as a result of differential mortality. Persons who were excluded from the study because they were deceased were probably more likely to be slightly older, male, nonwhite, ventilator-dependent, have neurologically complete injuries, and be injured during the 1970's than persons who were included in the study. However, there is no reason to believe the circumstances surrounding the injuries of persons who are now deceased would be any different from those of persons who were included in the study unless certain trends have occurred during the past two decades. Even if a slight bias occurred from differential exclusion of older data, it is the newer data that are most relevant to current and future prevention efforts. Moreover, the fact that demographic and injury severity characteristics of persons included in this study are consistent with those of previous studies suggests that any bias involving these characteristics should be relatively small.¹³⁻¹⁶

To the extent that alcohol and illicit drug use at the time of the injury is related to subsequent use, the effect of these items on the occurrence of SCI in swimming pool mishaps might be slightly underestimated by the exclusion of deceased persons. Also,

if certain injury circumstances typically produce more severe injuries, then the frequency of those circumstances might be underestimated.

There is no reason to believe the persons who could not be located who were still alive would answer the questions differently than persons who were successfully contacted. There were very few refusals among persons actually contacted.

The high number of unknowns for certain demographic characteristics occurred because one of the data sets in the NSCISC database does not contain those items. The high number of unknowns for associated injuries occurred because those items were not added to the database until 1986. It is not anticipated that any bias is caused by these unknown responses.

The validity of self-reported alcohol and drug involvement might also be questioned. In this study, blood alcohol data were available in the medical records of only 10 persons. All 10 tested positive and all 10 independently admitted that alcohol was involved in their injury. A notation in the medical record that alcohol was suspected but the test was not done occurred in an additional 27 instances. Again, all 27 of these persons independently reported that alcohol was involved in their injury. There was no evidence in the medical records that anyone who said that alcohol was not involved was not truthful. Therefore, in this study, the self-reported use of alcohol at the time of injury appears to be a valid measure of actual alcohol use. Since this was one of the more sensitive questions asked during the interview, it would appear that responses to other questions should also be valid, although the possibility of bias resulting from selective recall of persons being interviewed cannot be totally excluded, particularly when the injury occurred many years ago.

This study was not designed to estimate either the incidence of SCI occurring in swimming pools or whether any trends have occurred in the frequency of these injuries over time. However, several population-based studies suggest that the overall incidence of SCI in the United States is approximately 10,000 new cases per year.²⁶⁻²⁸ If the NSCISC database is representative of these injuries with respect to their causes, then it can be estimated that approximately 850 new spinal cord injuries occur each year as a result of a diving mishap.¹ Results of this study suggest that approximately 300 of those injuries will occur in swimming pools. This figure does not include persons who drown in swimming pools as a result of sustaining a SCI.

Increased frequencies of SCI for certain demographic groups should not be interpreted to mean that those persons are at higher risk for obtaining these injuries. To make such inferences, one must have information about the degree of exposure to possible injury (use of swimming pools, number of dives, etc.) that was not collected in this study.

In addition to the physical, social, and emotional consequences of SCI resulting from diving mishaps,

the economic sequences of these injuries are staggering. In present value 1992 dollars using a 2% discount rate, it has been estimated that total direct medical expenses and indirect costs resulting from lost wages and fringe benefits over the remaining lifetime of a person with SCI injured at age 25 average \$3,396,669 for persons with injury levels at C4 or above, and \$2,320,824 for persons with injury levels between C5 and C8.²⁹ These are the injury levels associated with diving mishaps. Therefore, it would appear that primary prevention programs can be highly cost-effective if just a single SCI can be prevented. This study has provided the necessary information to initiate such programs.

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