

DIVING AND SUBAQUATIC MEDICINE

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DIVING FATALITIES AND STATISTICAL INTERPRETATIONS:

INTRODUCTION

This chapter deals with statistics available on diving deaths and draws heavily on data obtained from the USA where the vast number of divers engaged in the pursuit (2 million Americans in skin and SCUBA in 1966<sup>1</sup>) has resulted in a considerable number of fatalities. These have been analysed in great detail and published in the University of Rhode Island (URI) Scuba Safety Report Series 2, 3 and 4.

Data on the causes of diving fatalities is necessary to outline deficiencies in diver training and diving conduct and to recognise trends and patterns in order to prevent future fatalities.

GENERAL

Schenck et al<sup>2</sup> compared their series of 135 cases from 1970, 132 cases 1971 (gathered from follow up of newspaper reports) and 261 cases from 1946-1964, 1966-1969 (gathered from personal communications and newspaper reports with the series of 94 cases gathered by Webster<sup>1</sup> from newspaper reports only. These are tabulated below.

Included in the table is an incomplete series of Australian fatalities compiled by Walker<sup>5</sup>.

**TABLE 1**  
**DIVING FATALITIES IN USA 1946-1970 AND AUSTRALIA 1965-1972**

	<b>Webster</b>	<b>URI</b>	<b>Walker</b>	<b>URI</b>	<b>URI</b>
	<b>1965</b>	<b>1946-64</b>	<b>1972-73</b>	<b>1970</b>	<b>1971</b>
		<b>1966-69</b>			
% Male skin divers	26.6	17.6		16.3	12.9
% Female skin divers	2.1	0.4		1.5	0.0
<b>Total skin divers %</b>	<b>28.7</b>	<b>18.0</b>	<b>26.5</b>	<b>17.8</b>	<b>12.9</b>
% Male SCUBA divers	69.2	81.2		76.3	81.1
% Female SCUBA divers	2.1	0.8		5.9	5.8
<b>Total SCUBA divers %</b>	<b>71.3</b>	<b>82.0</b>	<b>73.5</b>	<b>82.2</b>	<b>87.1</b>

*Snorkel diver* fatalities are clearly outweighed by SCUBA deaths in all series and there is a trend towards a declining proportion of skin diver deaths in recent years. It is likely the skin divers outnumber SCUBA divers but the skin diver faces fewer hazards and the scope of his dives is considerably restricted. Thus it seems understandable that the mortality incidence is less with this group.

SEX

Females accounted for only a small proportion of both skin and SCUBA deaths although this proportion seems to be increasing, possibly reflecting an increasing number of females participating in the sport. Denny and Read<sup>6</sup> recorded 1 female death (4.8%) in 21 cases from 1959-65 in Michigan, their results being derived from accident reports from the State Police. Their figures are comparable with the US figures for the same period.

Bayliss<sup>7</sup> noted 2 female (2.8%) deaths among 71 Australian fatalities between 1957-67, a similar incidence to the URI series<sup>2</sup> which drew many of its cases from a similar period. his figures were extracted from reports of government medical officers and coroners throughout Australia. Lowry and Thomas<sup>8</sup> (1974) found that females accounted for 18% of Australian divers who passed the diving medical examination in a series of 382. This would suggest that a smaller proportion of female divers is killed than males. However it may not be completely valid to relate these figures as the proportion of females successfully completing the medical examination does not necessarily represent the proportion actually diving.

AGE

**TABLE 2**  
**AGES OF DIVING FATALITY VICTIMS**

<b>Age</b>	<b>Webster 1965</b>	<b>URI 1946-64 1966-69</b>	<b>URI 1970</b>	<b>URI 1971</b>	<b>Bayliss</b>
10-15	4.1%	4.2%	7.8%	4.0%	0%
16-20	28.2	29.6	23.8	26.4	19.7
21-25	24.0	33.7	21.6	20.0	29.6
26-30	11.4	11.7	13.8	16.8	12.6
31-35	10.2	11.3	8.5	8.0	14.1
36-40	8.2	3.3	3.8	4.0	11.3
41-45	8.2	2.3	11.5	4.8	4.2
46-50	3.6	0.8	5.4	7.2	8.5
51-55	1.1	1.9	1.5	4.8	0
56-60	1.1	0.4	2.3	1.6	0
61-75	0	0.8	0	0.8	0
<b>TOTAL NUMBER</b>	<b>86</b>	<b>213</b>	<b>130</b>	<b>125</b>	<b>71</b>

In the reports mentioning the ages of victims most deaths were recorded in divers aged between 16-30. These victims were in the prime of youth and presumably at their peak of physical fitness. The reports of Bayliss and URI (1946-1969) found the highest incidence of deaths in the age group 21-25. However the latest URI series and Webster's series, found the highest incidence (Averaging 26%) in the age group 16-20, suggesting an increasing mortality rate among young divers in recent years. This age group accounted for only 16.5% of candidates for diving who passed medical examination reported in Australia by Lowry and Thomas, suggesting a disproportionately high incidence of fatalities in divers under 20.

The relative immaturity and/or inexperience of young divers are probably important factors in their demise.

EXPERIENCE

**TABLE 3  
EXPERIENCE OF VICTIMS**

	URI 1946-64	URI 1970	URI 1971	Denny and Read
First dive	7.8%	13.6%	14.3%	)
				)
First dive in open water	5.2	8.7	12.8	)
				)
Early open water (2-6 divers)	33.4	14.8	18.7	) 71.5%
				)
Some experience (more than 1 year)	24.2	30.7	28.6	)
				)
Considerable experience (several years)	13.6	16.0	20.8	)
				)
Very Experienced (commercial divers or divers with very good reputation)	33.4	14.8	18.7	) 28.5%
				)
				)
<b>TOTAL DIVERS</b>	<b>155</b>	<b>81</b>	<b>91</b>	<b>21</b>

The URI series showed that over one third of the deaths occurred in experienced divers (those with fewer than 6 dives), with an increasing proportion being killed on their first dive, the proportion reaching 14.3% in 1971. This URI paper implicated the indiscriminate hiring of equipment to novices in these fatalities, and also pointed out the important environmental difference between swimming pools where many novices are taught, and open water. Of the deaths, 13% were novices who died while undergoing instruction, half of whom were being taught by professional instructors.

Alarmingly also, those divers who would be considered experience (with over one year's experience) contributed over half the fatalities in the URI series. Those with many years experience comprised half of this group. It is probable that the high proportion of relatively experience divers being killed reflected the more ambitious dives they would tend to undertake, and a neglect of safety principles.

Denny and Read found 3 divers (14.2%) died during their first dive and a similar number died while under instruction. These figures are consistent with URI series. Fifteen of the divers (71.4%) were regarded by the authors as inexperience (with less than 2 years experience) in this series. These figures are also similar to the URI group.

Of 91 SCUBA cases where training was recorded in the URI series, 39% had no formal training and 31% had some course and held a certificate in the other cases there was some training of an unspecified nature. Among the 91 victims were 7 instructors.

Thus neither the possession of "experience" nor a certificate is adequate protection against diving fatalities.

Of 17 *snorkel divers* in the URI series, 19% were novices, 24% had some experience and 47% were very experienced. Although it is difficult to draw conclusions from small numbers, here again the experience diver is in the majority and lack of experience seems to be a less important factor in fatalities. Experience may bring with it a disregard for hazards and a competitive inclination to hazardous procedures such as hyperventilation prior to diving. Presumably experienced snorkel divers are more numerous, and are less likely to avoid hazardous situations. Bayliss reported three cases (4.3%) in his series in which the diver was known to practise hyperventilation. Of the 16 Australian deaths in 1973 reported by Walker, three (19%) occurred in swimming pools and resulted from unconsciousness and drowning following hyperventilation. Hyperventilation prior to diving is a hazardous practice and is probably a significant cause of skin diver mortality.

#### BUDDY DIVING

**TABLE 4**  
**ANALYSIS OF THE BUDDY SYSTEM RECEIVED CAREFUL ATTENTION IN THE URI REPORTS OF 1970 AND 1971**

	Skin	SCUBA	Skin & SCUBA combined
Alone 50%	11.3%	17.0%	
1 buddy	15.8	45.7	41.3
2 buddies	18.4	14.0	14.7
3 buddies	7.9	9.1	8.9
Several	7.9	16.3	15.0
Surface tender	0	3.6	3.1
<b>TOTAL NUMBER</b>	<b>38</b>	<b>221</b>	<b>259</b>

The importance of buddy diving has been long taught to divers. The high proportion of *snorkel diving* victims diving alone would seem to emphasise the consequence of ignoring this rule. These divers are also those most suited to rescue and resuscitation by a buddy since they are likely to be diving in relatively shallow water and are not prone to the effects of breathing compressed gases.

Surprisingly, however, the majority of SCUBA victims were diving with one or more buddies. In fact over 40% were with one buddy, the potentially most efficient buddy system.

These figures sometimes have been quoted by divers in defence of diving alone. However, as the URI report rightly point out, the figures may well indicate a failure of the application of the buddy system rather than a fault in the system itself. A buddy who is not physically attached to or in direct communication with his partner is merely another human swimming in the same ocean. In fact, the URI examined the activity of buddies in 1971, it found that in 42% of cases, the buddy lost contact with the victim during rescue, emphasising the importance of buddy lines.

In the 1970 and 1971 URI series only 7% and 6% respectively of all fatalities arose from cave diving o the figures are not significantly biased by multiple cave fatalities.

The URI group then examined the activity of buddies in 1971:

Buddy stayed with victim	29 %
Attempted buddy breathing	18
Buddy left water ahead of victim	11
Buddy lost victim on surface	14
Buddy lost victim underwater	28
<b>TOTAL NUMBER</b>	<b>85</b>

Of interest in these figures is the number of failed buddy breathing attempts. As pointed out by URI series there seems to be a need for training in buddy rescue techniques.

#### BUDDY BREATHING

URI studies 24 cases of failed buddy breathing in 1946-70 group. They stressed the following characteristics:

1. Over half were attempted deeper than 20 metres, the depth ranging from 2-45 metres, except for one fatality at 100 metres.
2. In no instances did the assisting buddy die while the rescuer survived (this should encourage would-be rescuers to share their air). The important point however is the advantage of having one's own regulator delivering air. This emphasises the advantage of octopus rigs.
3. In 29% of cases the victim or buddy's face mask was displaced, considerably complicating an already difficult operation.
4. There were 3 cases (12.5%) of air embolism. It is easy to imagine overinflation of the lungs occurring during the situation involving considerable victim anxiety, regulator sharing, purging and ascending.
5. There were 3 instances (12.5%) of the victim refusing to return the mouthpiece and fighting for it.

These figures certainly suggest a case for reconsidering buddy breathing as a rescue method. As the URI report points out, there is a vast difference between controlled buddy breathing in the pool or sheltered ocean environment during training and the critical emergency situation with a frightened and possibly hypoxic victim with limited visibility.

Except in the cave situation, there appears to be a good case for abandoning buddy breathing in favour of free ascents with the buddy guiding the victim to the surface, or for using an alternative source of air eg. octopus rig or air inflatable vest.

## EQUIPMENT FAILURE

*Regulators:* In the URI series there were only 4 cases (1.5%) mentioned. In one of these the regulator had been improperly assembled and in two cases regulators had been fouled with foreign material. Regulator failure does not seem to be an important factor.

In 1970-71 URI series 13% had run completely out of air and 6% had very little air left. It was stated that the lack of air was an important factor in these deaths. More widespread use of tank pressure gauges may help obviate this risk.

## LIFE VESTS

The URI series, considering vests worn and later checked, showed:

Vest worn, not used	31%
Vest worn, malfunction or no gas cartridge	33.3
Vest worn, inflated during accident	35.7
<b>TOTAL CASES</b>	<b>42</b>

In one third of cases where vests were required there was a malfunction. These reports referred to CO<sub>2</sub> cartridge vests which were then popular. The safer air inflatable vests are now being used more frequently

In a similar proportion of cases the vest failed to save the victim. The URI reports suggest that this fact is partly explained by the poor quality of some vests available with inadequate buoyancy or failure to keep the unconscious victim's face clear of the water.

## LOCATION

	URI SERIES
Sea	58.9%
Fresh Water	30.3%
Cave	10.8%
<b>TOTAL CASES</b>	<b>360</b>

Cave deaths constitute a considerably proportion of deaths. In Australia in 1973-74 of 13 diving deaths, 30% occurred during cave diving.<sup>9</sup>

The high proportion of fresh water deaths may reflect the American continent's large inland waterways and the practice of quarry diving, and may not be applicable to other countries.

## CAVE DEATHS

Most of the cave deaths in URI and Walker's series resulted from what could only be described as foolhardy dives. In 1946-70 series, 82 cave or sinkhole deaths were recorded. Only 6% of victims were considered adequately equipped. Twenty five per cent were diving on air in excess of 40 metres, at which depth the risks of poor visibility and a restricted environment are compounded by the problem of nitrogen narcosis. Fifty per cent of victims either had no lifeline to the surface, or left it to explore further.

In a tragic quadruple sinkhole fatality in Australia in 1973, eight divers dived to depth in excess of 60 metres with no shot line, reserve tanks, or safety lines. Four of the group were fortunate to survive.

#### DAY DISTRIBUTION

As expected, the majority of cases occurred on weekends - Sunday most commonly, followed by Saturday and Monday. Fatalities were more common in summer than in winter.

#### WEATHER

In half the URI cases the weather was calm, suggesting that weather per se is not of dominant importance.

#### OTHER FACTORS

Less than 1% of deaths were caused by shark attack, contaminated air or spearguns in the URI series. Injuries to the diver from a boat caused the death of over 3% of the cases in the latest URI report.

#### DEPTH OF BODY

The URI series showed that in half the cases the body was recovered in water less than 30-40 feet in depth. In the Denny and Read series, 85% of the 21 cases were in depth less than 30 feet. It is in this depth that one would expect the novice to dive with some feeling of security.

#### TIME UNTIL RECOVERY

In only 34% of the cases in the URI 1970-71 reports was the body recovered within 15 minutes. Resuscitation was attempted on most of these victims, but the delay in recovery made the efforts futile.

In only one fifth of the cases was the body recovered in less than 5 minutes when a good chance of resuscitation might be available. This again reflects the need for an efficient buddy system.

#### AUTOPSY FINDINGS

**TABLE 5  
AUTOPSY FINDINGS**

	URI 1970 %	URI 1971 %	Denny & Read %	Bayliss %	Okalyi %	Miles %
Asphyxiation and drowning	49	56.6	37.5	63.3	12.5	44.0
Pulmonary Barotrauma	17.6	26.1	50.0	15.5	58.3	10.0
Head Injury and Drowning	9.8	4.3	0.0	0.0	0.0	0.0
Myocardial Infraction	9.8	2.2	12.5	0.0	0.0	0.0
Vomiting and Aspiration	5.9	2.2	0.0	0.0	0.0	0.0
Propeller Injuries	3.9	0.0	0.0	0.0	0.0	0.0

	URI 1970 %	URI 1971 %	Denny & Read %	Bayliss %	Okalyi %	Miles %
Drowning after other medical illness, eg. diabetes	0.0	0.0	0.0	8.5	8.4	6.0
Anoxia (usually on O <sub>2</sub> equipment)	0.0	0.0	0.0	0.0	0.0	16.0
O <sub>2</sub> Toxicity	0.0	0.0	0.0	0.0	0.0	10.0
Shark attack	0.0	0.0	0.0	0.0	0.0	6.0
Others	0.0	0.0	0.0	0.0	0.0	6.0
<b>TOTAL CASES</b>	<b>51</b>	<b>45</b>	<b>8</b>	<b>71</b>	<b>24</b>	<b>51</b>

As expected drowning is the most common cause of death and, where possible those factors which have incapacitated the patient leading to the drowning have been separated. It is interesting to note that the second most common cause of death in series other than Miles<sup>10</sup> and Denny and Read's is pulmonary barotrauma (usually resulting in air embolism).

Okalyi's figures deal with Torres Strait Islander pearl divers who are not typical of sport divers. Helmet diving was used and any mishap was usually followed by a free ascent, often leading to pulmonary barotrauma, decompression sickness, or both. The divers rarely followed standard decompression tables and commonly developed decompression sickness. The low incidence of uncomplicated drowning is probably explained by the divers being always well attended from the surface.

The URI 1946-69 survey mentioned autopsies in only two categories. These were 23 cases of lung over pressure and 5 of myocardial infarction.

It has been suggested in the URI series that the increasing incidence of pulmonary barotrauma reported was an indication of increasing awareness of the injury by coroners and that air embolism occurred in a considerably greater proportion of cases than was found at autopsy. Of the 101 cases screened in the 1970 URI report for symptoms suggesting air embolism as observed by eye witnesses, 28 speculative cases emerged (17%). Eight of these were diagnosed at autopsy as air embolism. Since the autopsy technique required to detect air embolism is critical it is quite possible that cases remain undiagnosed. Denny and Read found symptoms suggestive of air embolism observed in eye witness reports in 52% of 21 victims. Autopsies were performed on 4 of these cases and pulmonary barotrauma with air embolism was demonstrated. There were only 8 autopsy reports mentioned in the series.

Miles' cases are drawn from recreational, professional and military divers and it is not clear whether they are obtained from autopsy findings. The spectrum of causes of death is considerably broader since potentially hazardous rebreathing equipment is commonly used by military divers and rarely used by civilians. The high incidence of deaths subsequent to medical disease, combined with the probability that some of the pulmonary barotrauma deaths involved a pre-existing lung condition, emphasises the need for regular medical examinations.



## CONCLUSIONS

The bulk of the data presented was gathered in the United States. However the diving patterns are not unlike those in Australia and other developed nations, and the findings are probably quite relevant to these countries. Where comparable figures for Australia exist, in general they show similar trends to the US figures.

### *Victims of Diving Fatalities*

Fewer skin (snorkel) divers are killed than compressed air divers even though there are probably more snorkel divers operating. It seems reasonable that the surface swimmer who makes intermittent excursions to relatively shallow depths and breathes air at atmospheric pressure faces fewer risks than the compressed air diver.

### *Sex of Victims*

Fewer females are killed in diving accidents than males, probably reflecting the relatively small numbers of females in the diving population. The proportion of female fatalities appears to be increasing, at least in the USA, as more females participate in the sport.

### *Age*

The majority of victims are drawn from the young and undoubtedly fittest group of the diving population, most being in the 16-25 age group. Clearly youth and physical fitness, while desirable in divers, are no insurance against fatality.

### *Buddies*

The majority of skin divers die alone emphasising the need for buddy diving.

Surprisingly however the majority of SCUBA divers die in spite of their lip service to the buddy system. The important question is whether the buddy system is being applied correctly. A diver who cannot contact his buddy has none. In many cases the buddy failed in his attempt to rescue the victim through losing contact with him (no buddy line) or through failed buddy breathing.

There appears to be a need for training in all aspects of buddy rescue.

### *Equipment Failure*

Regulator failure was not an important factor. In one third of cases where an attempt was made to use CO<sub>2</sub> inflatable vests, there was a malfunction. Often inadequate vests were used and in one third of cases the vest failed to save the victim. The newer air vest may prove considerably safer.

### *Location*

The majority of deaths occurred in safe water. Ten per cent of fatalities occurred in cases, despite the relatively low incidence of cave diving. Most cave deaths resulted from poorly equipped and ill-conceived dives.

### *Day/Month Distribution*

Most deaths occurred on weekends during the summer months.

### *Weather*

In half the cases the weather was calm.

### *Depth of Recovery*

In 50% of cases, the body was recovered from depth less than 30 feet. This is a depth of water in which novices could be expected to feel more confident.

### *Times of Recovery*

In only one third of cases was the body recovered in time for any hope of resuscitation. This again reflects deficiencies in the application of the buddy rescue system.

### *Cause of Death*

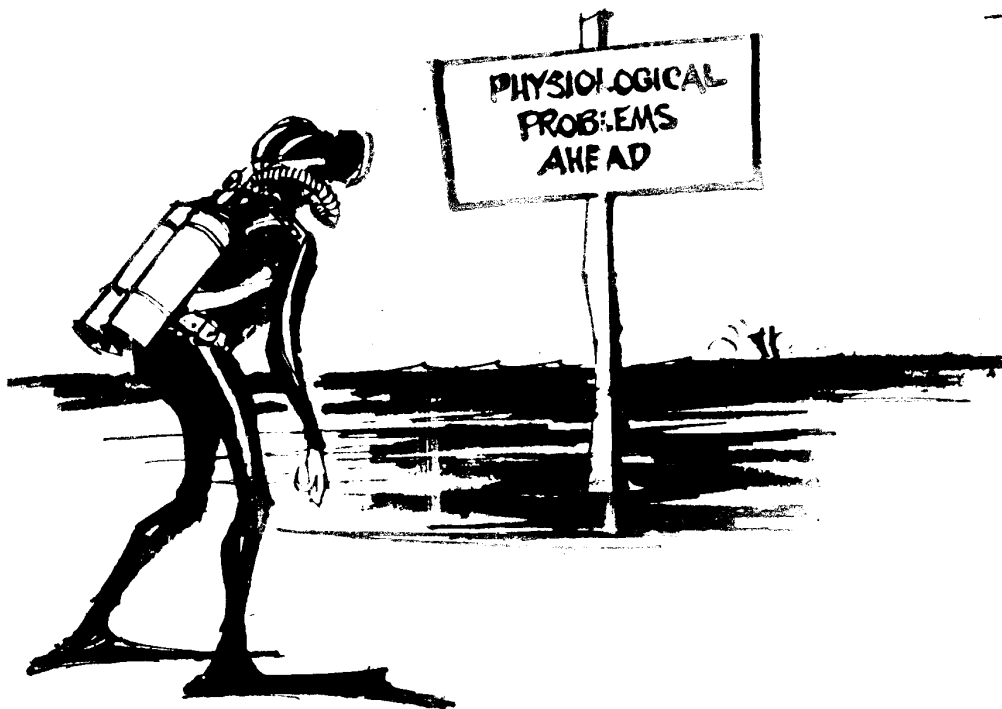
Drowning is often the ultimate cause of death and comprises the majority of autopsy findings.

Pulmonary barotrauma was diagnosed in 10-20% of most series.

A similar percentage of fatal decompression sickness was recorded in an Australian series.

The autopsy technique in diving fatalities is critical and more cases of air embolism may be detected as techniques are refined.

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**" I see that SPUMS dives here ! "**