RESEARCH REPORT 11-70

REVIEW OF DIVING ACCIDENT REPORTS 1968

1 December 1970

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WASHINGTON NAVY YARD
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13. ABSTRACT

All diving accidents reported to the U.S. Navy Experimental Diving Unit during 1968 were coded and statistically analyzed. The incidence of decompression sickness was the most common accident to occur to divers. Those decompression accidents involving military divers were separated, and the various variables associated with this type of accident were analyzed. Several variables, such as the diver's physical characteristics, environmental diving conditions, and the treatment and treatment outcome were compared with similar data for the 1961-1967 base period. Differences between the base period and 1968 are shown in percentages. In addition, significant and interesting case histories of accidents that occurred in 1968 are presented.

This study confirmed several observations noted in previous reports. A number of items related to decompression sickness accidents changed in 1968 to a significant degree.

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ABSTRACT

All diving accidents reported to the U. S. Navy Experimental Diving Unit during 1968 were coded and statistically analyzed. The incidence of decompression sickness was the most common accident to occur to divers. Those decompression accidents involving military divers were separated, and the various variables associated with this type of accident were analyzed. Several variables, such as the diver's physical characteristics, environmental diving conditions, and the treatment outcome were compared with similar data for the 1961-1967 base period. Differences between the base period and 1968 are shown in percentages. In addition, significant and interesting case histories of accidents that occurred in 1968 are presented.

This study confirmed several observations noted in previous reports. A number of items related to decompression sickness accidents changed in 1968 to a significant degree.

SUMMARY

PROBLEM:

(1) To evaluate the diving accidents reported in 1968 and to compare the data with similar data established from previous report periods;

(2) To determine and analyze those factors and variables which have a positive correlation to decompression sickness amoung military divers;

(3) To present significant case reports which would be of interest and present information which could be applicable to current diving operations.

(4) To prepare the report in a format which would inform the student, the investigator, the operational diver, and the medical personnel of the incidence of decompression sickness and the factors involved.

PROCEDURES:

(1) A preliminary analysis of the 1968 diving accidents was made. The most common accident to occur to military divers was decompression sickness. Accidents involving decompression sickness amoung military divers were separated and analyzed. The distribution and percentage changes for the various variables associated with decompression sickness were prepared in an easily understood form. The distribution and percent change from the base period 1961-1966, and the 1967 period were compared with the 1968 data.

(2) Case reports for accidents which were considered to be of particular significance and interest to members of the diving community were reviewed and summarized.

(3) Previous reports on diving accidents and the correlation between various factors involved are included in the appendices.

RESULTS:

(1) This study confirms the data from previous reports that the outcome of treatment is interrelated with the time delay between the onset of symptoms and the start of treatment.

(2) When comparing the accidents that occurred in 1968 with those of previous years, significant differences are shown in the following variables:

VARIABLE	DIRECTION OF CHANGE
QUALIFICATION OF MILITARY DIVERS AFFECTED BY DECOMPRESSION SICKNESS	
Master Diver	Decrease
Diver First Class	Increase
Diver Second Class	Decrease
Underwater Swimmer	Increase
Submariner	Increase
NUMBER OF PREVIOUS REPORTED DECOMPRESSION ACCIDENTS	
No Previous Accidents	Decrease
Two Previous Accidents	Increase
Three Previous Accidents	Increase
PURPOSE OF DIVE	
Training Dive	Decrease
Experimental	Increase
Requalification	Decrease
Working	Decrease
Sport	Decrease
SITE OF DIVE	
Wet Pot	Increase
Dry Chamber	Decrease
Escape Tank	Decrease
Altitude Exposure	Increase
Open Water	Decrease
TYPE OF DIVING EQUIPMENT	
Shallow Water Mask	Decrease
Hookah	Increase
Deep Sea (Air)	Decrease
Deep Sea (HeO_2)	Decrease
Chamber Dive	Decrease
Closed Circuit SCUBA	Decrease
Semi-Closed Circuit SCUBA	Increase
Open Circuit	Increase

VARIABLE	DIRECTION OF CHANGE
BREATHING MEDIUM	
Air	Decrease
Helium-Oxygen Mix	Increase
Nitrogen-Oxygen Mix	Increase
HeO_2N_2	Decrease
Air and Oxygen	Increase
BOTTOM TIME OF DIVE	
Ten Minutes and Less	Decrease
Twenty Minutes	Decrease
Thirty Minutes	Increase
Forty Minutes	Decrease
Fifty Minutes	Decrease
Sixty Minutes	Increase
Sixty Minutes and Over	Increase
TYPE OF WORK	
Mild	Decrease
Moderate	Increase
Heavy	Decrease
REPORT OF ONSET OF DECOMPRESSION SICKNESS SYMPTOMS	
During Dive	Increase
Up to 140 minutes and Over	Increase
From 140 Minutes and Over	Decrease
TYPE OF SYMPTOMS	
Localized Pain	Decrease
Muscular Weakness	Decrease
Visual Disturbances	Increase
Unconsciousness	Decrease
Nausea	Increase
Paresthesia	Increase
LOCATION OF SYMPTOMS	
Generalized	Increase
Right Side	Decrease
Upper Half	Decrease
Shoulder	Increase
Leg and Knee	Increase

VARIABLE	DIRECTION OF CHANGE
TIME TO RELIEF OF SYMPTOMS	
Ten Minutes and Less	Decrease
Ten to Sixty Minutes	Increase
Sixty Minutes and Over	Decrease
DEPTH OF RELIEF OF SYMPTOMS	
Zero to Ninety-nine Feet	Increase
Ninety-nine to Over 165 Feet	Decrease
TYPE OF TREATMENT TABLE USED	
Table 1	Decrease
Table 2	Decrease
Table 3	Decrease
Table 5	Decrease
Table 6	Increase
Other Treatment	Increase

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Section 1

INTRODUCTION

1.1 BACKGROUND

1.1.1 Prior to 1963, diving accident reports involving both military and civilian divers were not systematically analyzed or reviewed. In 1963, Lt. J.C. Rivera prepared a comprehensive report (23) of 935 decompressions sickness accidents involving military divers. This report evaluated the various factors involved and provided a basis for subsequent accident reports and studies.

1.1.2 Diving accident reports which have been prepared since Lt. Rivera's effort have been concerned with incidence of decompression sickness among military divers. This type of accident is the most prevalent among divers. It has been the purpose of these reports and analyses to identify those factors and variables which have a positive correlation with the incidence of decompression sickness among divers. If those factors and variables could be identified, new procedures and techniques could be applied for the purpose of reducing the incidence of decompression sickness among divers.

1.2 PRESENT STUDY

1.2.1 This report is concerned with diving accidents involving both military and civilian divers during the reporting period of 1968. The emphasis of the report is on the incidence of decompressions sickness among military divers. Various factors, such as the diver's physical characteristics, diving qualifcations and history of previous accidents are related to the incidence of decompression sickness. Other factors, associated with the conditions of the dive such as diving apparatus, breathing media and bottom time are also related. The report examines these factors in order to determine and present trends that are involved in decompression sickness accidents. These trends will be derived from a comparison of the present report period with past report periods. This report will also present data on other diving accidents and include summaries of accidents which are of interest to the diving community.

1.2.2 The information which forms the basis for this report is provided by accident reports submitted from various diving activities, and include both military and civilian divers. It should be noted that some of the factors involved in the diving accident report may reflect the subjective interpretation of the personnel preparing a diving accident report. For instance, the requirement to distinguish between the body build of a diver in categories of "slender," "medium," "heavy," or "obese," is probably based on a personal estimation. In these categories, the information is susceptible to the personal bias of the individual preparing the report.

1.2.3 Factors that require a numerical definition, such as depth of water, height, weight, and age, can be considered as being more objective but still subject to error. Since complete information concerning all dives made is not being presented in this report, a firm determination should not be presumed on the significance between the factors and the incidence of decompression sickness. The information presented should be considered as trends and as providing information concerning factors that are most likely to be involved in decompression sickness accidents.

1.3 PROCEDURE

1.3.1 The diving accident reports for 1968 were reviewed and divided into various categories. The largest single category was determined to be decompression sickness. These accident reports are given special emphasis and presented with the diving conditions and physical characteristics of the divers. The distribution of the factors involved with the 1968 decompression accidents are compared with similar data obtained from the 1961-1966 and the 1967 reporting periods. Significant differences are described and the arithmetic mean and standard deviation are shown for each appropriate factor involved.

1.3.2 The incidence of air embolism and barotrauma were the next most prevalent types of accidents during 1968. These types of accidents are given slightly more detail than other types of accidents.

1.3.3 Summaries of selected research reports of the U.S. Navy Experimental Diving Unit on diving accidents are provided in Appendices A through F of the report for convenient reference.

Section 2

PRELIMINARY ANALYSIS

2.1 DIVING ACCIDENT SUMMARY, 1968

2.1.1 During 1968, there were a total of 137 Diving Accident Reports submitted to the Navy Experimental Diving Unit (EDU). Table 1 gives a summary of these accidents.

Table 1

Summary of Diving Accidents During 1968

TYPE OF ACCIDENT	CIVILIAN	MILITARY	TOTAL
Drownings	2	2	4
Decompression Sickness	25	55*	80
Air Embolism	4	5*	9
Pneumothorax	1	1	2
Mediastinal Emphysema	1	2	3
Carbon Dioxide Poisoning		3	3
Oxygen Poisoning	1	3	4
Barotrauma		21	21
Injuries		5	5
Near Drownings	2		2
Other	2	2	4
TOTAL ACCIDENTS	38	99	137

* Includes Foreign Nationals serving in the armed forces of their countries.

2.2 DECOMPRESSION SICKNESS ACCIDENT CASES

2.2.1 During 1968, a total of 80 decompression sickness accident reports were submitted to EDU. This comprised approximately 58 percent of all accidents reported. In comparison to the 1967 reporting period, a slight percentage decrease occurred. During 1967, decompression accidents totaled 67 incidents or approximately 65 percent of all accidents. No fatalities involving decompression accidents occurred during 1968.

2.2.2 Table 2 gives a comparison between the 1967 and the 1968 reporting periods for decompression sickness accidents. The percentage of decompression sickness accidents reported for the two periods involving military personnel did not change.

Table 2

Comparison Between Total Accidents and Decompression Sickness Accidents During 1967 and 1968

1967

Total Accidents	103
Decompression Sickness Accidents	67

Military			Civilian		
No.	% of Total	% of Decomp.	No.	% of Total	% of Decomp.
46	45%	69%	21	20%	31%

1968

Total Accidents	137
Decompression Sickness Accidents	80

Military			Civilian		
No.	% of Total	% of Decomp.	No.	% of Total	% of Decomp.
55	40%	69%	25	18%	31%

2.2.3 Decompression sickness accidents involving civilian divers for the 1967 and 1968 reporting periods show no appreciable percentage change. Reported decompression sickness accidents for 1967 represented 65 percent of total accidents. For the 1968 period, decompression sickness accidents were 58 percent of the total accidents, which represented a 7 percent decrease.

2.2.4 Table 3 shows the results of therapy for both civilian and military decompression cases. A substantially higher number of the civilian cases failed to respond to treatment than did military cases. Since treatment in both instances was the same, differences in the results are due to other factors. These findings are similar to the treatment data reported for the 1967 period.

Table 3

Outcome of Treatment for Military and Civilian Decompression Sickness Accidents During 1968

OUTCOME OF TREATMENT	MILITARY CASES		CIVILIAN CASES	
	Number	Percent	Number	Percent
Complete Relief	44	80.0	9	36.0
Substantial Relief	7	12.7	8	32.0
Substantial Residual Symptoms	1	1.8	6	24.0
Recurring Symptoms	3	5.5	2	8.0
TOTAL CASES	55	100.0	25	100.0

2.2.5 The poor response to treatment, which characterized civilian decompression sickness accidents, relates to two main factors: (1) inadequate or complete lack of prescribed decompression procedures during diving; and (2) prolonged delay between onset of symptoms and start of therapy. In cases in which symptoms persisted after therapy, it was found that most patients had ignored decompression schedules. In two instances, divers had performed dives to 135 and 150 feet, respectively, without using any decompression. Another case involved a diver who had made five successive dives deeper than 140 feet with less than 10 minutes of surface time between each dive. No decompression schedules were followed. The patient developed cyanosis and went into shock during therapy. However, he did recover after treatment.

2.2.6 Table 4 gives treatment results for the reported 25 civilian cases. Usually when the patient did not respond to the initial treatment table, a higher table was used for retreatment. The one case in which the patient was initially treated on Table 6 and retreatment on Table 3A was based on the physician's decision that more oxygen would be of little value.

Table 4

Results of Decompression Sickness Accident Treatment for the Reported 25 Civilian Cases

INITIAL TREATMENT	CASES TREATED	RESULTS		RETREATMENT TABLE	FOLLOW-UP OR FINAL RESULTS
Table		Relief	Failure		
1	2	1	1	Table 6	Unknown
2	1		1	None	Residual
3	1	1			
5	8	2	6	Mod.Tab.5 or 6	Relieved
				None	Relieved
				Mod.Tab.5 or 6	Relieved
				None	Unknown
				None	Relieved
				None	Unknown
6	8	5	3	None	Unknown
				None	Relieved
				None	Minor Residual
Mod. 5 or 6	4		4	Table 3	Substantial Residual
				Table 6	Relieved
				Table 6	Minor Residual
				None	Relieved
Other Pressure Treatment	1		1	None	Substantial Residual
Totals	25	9	16		
Percents	100%	36%	64%		

2.3 AIR EMBOLISM ACCIDENT CASES

2.3.1 During 1968 a total of nine air embolism accident cases were reported. The incidence of this accident was almost evenly distributed between military and civilian divers (refer to Table 1). One of the military cases involved a submariner of the Japanese Navy.

2.3.2 Air embolism, which is caused by holding the breath during ascent, occurs chiefly in inexperienced personnel. Most of the military personnel reported were involved in training exercises. The civilian cases of air embolism usually involved sport divers and usually individuals with little diving experience.

2.3.3 None of the divers affected by air embolism had to make an emergency ascent during diving. It is, therefore, conceivable that the accident rate for this type of accident could be reduced substantially by proper training.

2.4 CIVILIAN AIR EMBOLISM FATALITY

2.4.1 One of the four civilian air embolism cases reported resulted in a fatality. The diver involved ascended after a 195-minute-bottom-time dive from a depth of 40 feet. The patient suddenly became unconscious and never really regained full consciousness. Approximately 10 to 13 hours after the accident, treatment was started and the patient was recompressed twice to 165 feet.

2.4.2 Two decompression chamber tenders were affected slightly during and after the treatment for the fatal air embolism case. One tender developed susternal chest pain, which was especially noticeable when breathing oxygen. This was diagnosed as being caused by a bronchial condition. The other tender developed pain and tenderness in his right knee, which was related to kneeling on the cold floor of the decompression chamber.

2.5 MILITARY AIR EMBOLISM CASES

2.5.1 Four of the five military cases treated for air embolism occurred during submarine escape training exercises. One case that displayed recurring symptoms after pressure treatment involved a student who had a previous respiratory illness in 1966. Although the patient had expelled his breath correctly during his buoyant ascent and was breathing normally, it was determined that he had suffered involuntary air trapping in the area of his lung which had been damaged during his illness. After 24 hours of observation, the patient was normal.

2.6 OTHER MILITARY ACCIDENT CASES

2.6.1 The second most prevalent type of diving accident involving military personnel during 1968 was barotrauma. No civilian accidents were reported in this category. Approximately 75 percent of the cases involved Student personnel undergoing Training at the Underwater Swimmers School, Key West, Florida. The average age of the students involved was 21.4 years. The average age of other divers experiencing barotrauma was 27 years. The difference in age is not significant, but the reporting of this type of accident by school facilities may reflect either a closer supervision of student personnel or a tendency of more experienced divers to ignore barotrauma symptoms unless they are of such a nature to restrict their normal activities. Also, a change in medical support personnel at a diving facility would tend to initially increase the number of reports being submitted.

2.6.2 One diver experienced a hearing loss during decompression from a 350-foot-60-minute bottom time experimental dive using Mk IX rig. This accident was designated as a barotrauma, although it did have some symptoms of decompression sickness. The diver was recompressed to 165 feet, and the symptoms disappeared.

2.6.3 The only accidents involving injuries were reported by military personnel. One injury resulted in a fatality. The cause of death was due either to a blow on the head or drowning while unconscious. The accident was caused by a SCUBA air tank coming loose from the back of a support diver, which struck the patient on the head. Normal safeguards and correct predive procedure could have prevented this accident.

2.6.4 One injury was caused by ingestion of barolyme mixture during a dive using the Mk VI SCUBA apparatus. Flooding of the apparatus caused the diver to use the by-pass, and the barolyme mixture was forced into the diver's mouthpiece. The report stated that the flooding was due to a loose adjusting valve. A design deficiency study may be required to prevent recurrence of this type of accident.

2.6.5 Three of the four cases of oxygen toxicity involved military student divers. Two of the incidents occurred during oxygen tolerance tests.

Section 3

MILITARY DECOMPRESSION SICKNESS ACCIDENTS

3.1 GENERAL DISCUSSION

3.1.1 During 1968 the incidence of decompression sickness among military divers was the largest single category of all reported diving accidents. A total of 55 cases involved military personnel. This total was approximately 40 percent of all reported accidents or 69 percent of all decompression accidents reported for 1968.

3.1.2 This section of the report is concerned with analyzing the incidence of decompression sickness accidents among military divers. Several factors, such as the divers' physical characteristics and the diving conditions will be presented and compared with similar data from earlier reports. This information is presented here only for the purpose of determining trends which are associated with decompression sickness. The findings of this report should not be used as a basis for initiating procedures or decisions which are not supported by existing regulations and diving procedures.

3.1.3 There is a wide-spread belief among the members of the diving community that the physical characteristics of divers, such as weight, age, and weight-to-height ratio, are related to incidence of decompression sickness. A strong relationship has been demonstrated between age and the susceptibility of aviation bends (6,13). Decompression sickness can result from the impairment of the effusion of inert gas from body tissue, and poor blood circulation can drastically hinder the elimination process. Hence, age, which is associated with decreased efficiency in the circulatory system (13), relates to decompression sickness.

3.1.4 The relevancy of the physical characteristics of military divers to the incidence of decompression sickness during 1968 requires an analysis of the physical characteristics and dives completed by all military divers. This complete data is not available at this time.

3.1.5 In addition to the physical characteristics of military divers involved in decompression accidents, several diving procedural factors are also important. These include depth of water, breathing medium, and the number of dives made within a 12-hour period prior to the accident. Both the physical characteristics and procedural factors are compared with similar data provided in earlier reporting periods.

3.2 INTERPRETING THE GRAPHS

3.2.1 The information presented in graph form shows percentages of accidents within each category. The graphs compare information between the incidence rates for the period 1961-1966 and the 1968 reporting period. These graphs show trends and differences in those factors considered to be most relevant to decompression sickness accidents.

3.2.2 The number of dives presented in each of the graphs will vary. This is due to incomplete information on the accident report.

3.2.3 The arithmatic mean, standard deviation, and the minimum and maximum are given for each of the factors shown in the graphs.

3.3. PHYSICAL CHARACTERISTICS OF MILITARY DIVERS AFFECTED BY DECOMPRESSION SICKNESS

3.3.1 The accident reports submitted provide the information on the physical characteristics of divers involved in decompression accidents. Although the majority of reports contain the necessary information, a few reports were not complete.

3.3.2 Table 5 shows the number and percent of divers with specific body build related to the initially recorded organ system which displayed decompression symptoms. Only the initial symptom was used, although multiple symptoms were apparent in the majority of cases. Most of the divers are within the "medium" body build category which probably reflects the average body build of all military divers. The most prevalent organ system symptom was Musculoskeletal Pain.

Table 5

Decompression Accident Cases of Military Divers of Specific Body Build, Compared with Initial Symptom

No. of Cases: 55

INITIAL SYMPTOM	SLENDER BODY BUILD Cases Number	Percent	MEDIUM BODY BUILD Cases Number	Percent	HEAVY BODY BUILD Cases Number	Percent
Musculoskeletal Pain	7	100.0	28	75.7	6	54.5
CNS Motor			1	2.7		
CNS Sensory			1	2.7	2	18.2
CNS Spl. Sense			1	2.7		
Skin Bends			4	10.8	3	27.3
Generalized			2	5.4		
TOTAL CASES	7	100.0	37	100.0	11	100.0

3.3.3 Table 6 shows the body build or military divers and the outcome of the treatment. Distribution of the cases within the various body build categories is fairly even. The two cases involving flying personnel are counted in the "heavy" body build category. None of the divers in the "slender" category had recurring symptoms; one case in the "heavy" category has recurring symptoms after the initial treatment.

Table 6

Body Build of Divers Affected by Decompression Accidents in 1968 Related to Outcome of Treatment

No. of Cases: 55

OUTCOME OF TREATMENT	SLENDER BODY BUILD		MEDIUM BODY BUILD		HEAVY BODY BUILD	
	Cases Number	Percent	Cases Number	Percent	Cases Number	Percent
Complete Relief	6	85.7	31	83.8	7	63.6
Substantial Relief	1	14.3	3	8.1	3*	27.3
Residual Substantial			1	2.7		
Recurring Symptoms			2	5.4	1	9.1
TOTAL CASES	7	100.0	37	100.0	11	100.0
PERCENT OF TOTAL CASES	12.7		67.3		20.0	

* Includes two cases of altitude bends.

3.3.4 The three cases of recurring symptoms in Table 6 were from the same diving activity. Each diver was diving to a depth of 149 feet for a bottom time of 30 minutes. This accident is summarized in Section 4.

3.3.5 Decompression sickness among civilian divers during 1968 shows a significant difference in the various body build categories. For the 23 civilian cases used, approximately 22% were classified as "slender"; 44% as "medium"; 26% as "heavy"; and 8% as "obese". This difference in body build for civilian divers, compared to military divers, probably reflects the better physical condition of military divers.

3.3.6 The average age of military divers affected by decompression sickness during 1968 was 30 years. The standard deviation for this sample was 4.2 years. The average age of divers was the same for the 1961-1966 and 1967 report periods and this possibly reflects the average age of all military divers.

3.3.7 Several studies have established a relationship between the age of a diver and susceptibility to decompression sickness in cases involving repeated exposures to altitude (13).

3.3.8 Table 7 gives the ages of divers affected by decompression sickness during 1968 compared with the outcome of the treatment. The three cases with recurring symptoms are skewed toward the younger divers. The information does not agree with earlier findings that age is related to the incidence of decompression sickness. The sample was small. A larger sample may support the previous studies.

Table 7

Age of Military Divers Affected by Decompression Sickness Compared with Outcome of Treatment

No. of Cases: 55

OUTCOME OF TREATMENT	AGES UNDER 25		AGES 26-30		AGES 31-35		AGES OVER 36	
	Cases Number	Percent	Cases Number	Percent	Cases Number	Percent	Cases Number	Percent
Complete Relief	6	85.7	19	82.6	16	76.1	3	75.0
Substantial Relief			3	13.0	3	14.3	1	25.0
Residual Substantial					1	4.8		
Recurring Symptoms	1	14.3	1	4.3	1	4.8		
TOTAL CASES	7	100.0	23	99.9	21	100.0	4	100.0
PERCENT OF TOTAL CASES	12.7		41.8		38.2		7.3	

3.3.9 Figure 1 shows the weight of divers affected by decompression sickness for the 1961-1966 and the 1968 period. The average weight for the 1968 reporting period increased slightly in comparison with the 1961-1966 period.

3.3.10 During the 1968 period the weight interval 170-179 increased significantly. The weight intervals 140-149 and 150-159 showed a percentage decrease for the same period.

3.3.11 Table 8 relates the weight of divers to the outcome of the treatment. In the three cases of recurring symptoms the weights of the divers were over 185 pounds.

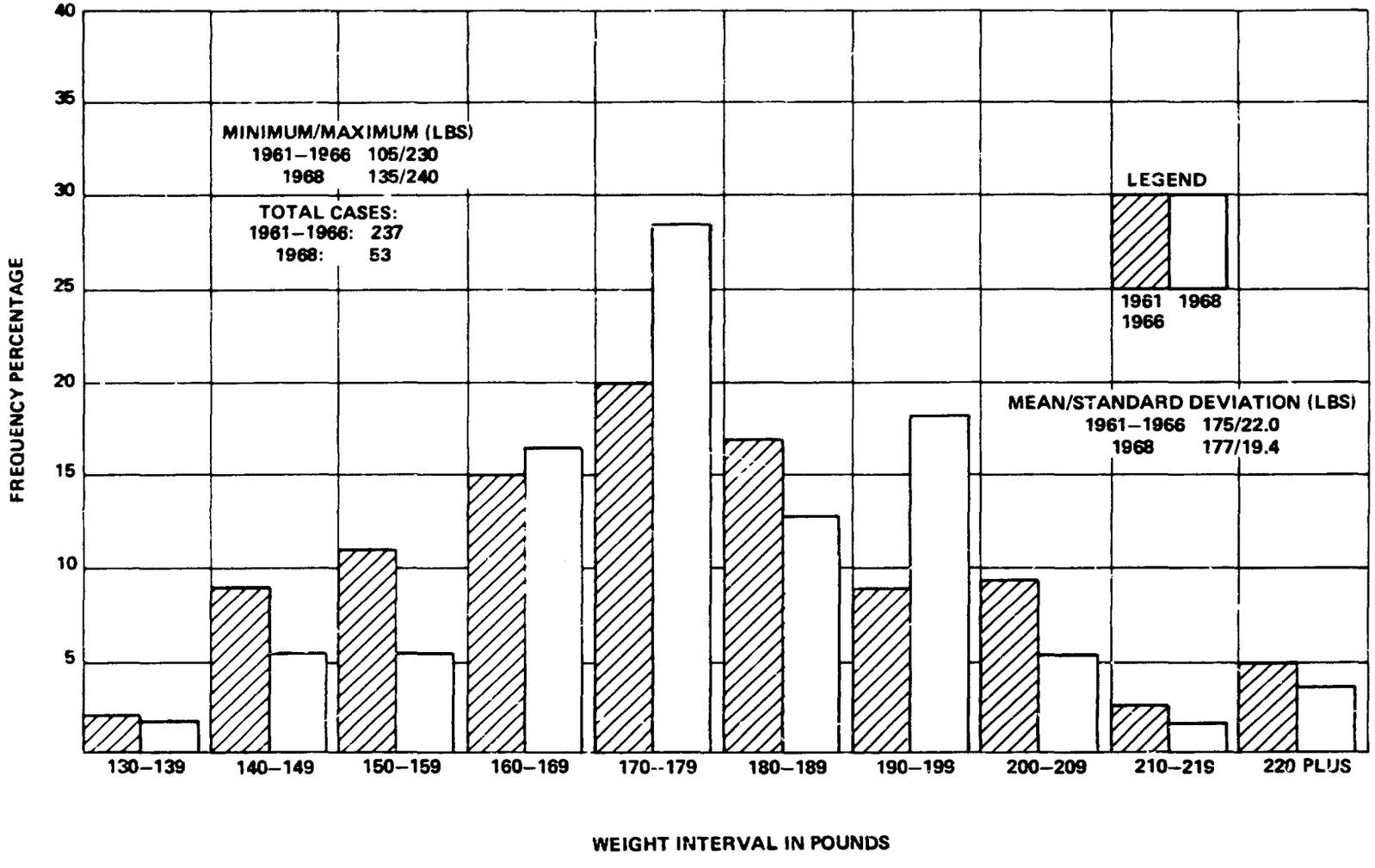
Table 8

Weight of Divers Affected by Decompression Sickness in 1968 Compared with Outcome of Treatment

No. of Cases: 54

OUTCOME OF TREATMENT	WEIGHTS UNDER 150		WEIGHTS 150-170		WEIGHTS 171-190		WEIGHTS 191-210		WEIGHTS OVER 210	
	Cases No.	%	Cases No.	%	Cases No.	%	Cases No.	%	Cases No.	%
Complete Relief	3	75.0	19	95.0	14	73.7	7	77.8	1	50.0
Substantial Relief	1	25.0	1	5.0	2	10.5	1	11.1	1	50.0
Residual Substantial					1	5.3				
Recurring Symptoms					2	10.5	1	11.1		
TOTAL CASES	4	100.0	20	100.0	19	100.0	9	100.0	2	100.0
PERCENT OF TOTAL CASES	7.4		37.0		35.2		16.7		3.7	

FIGURE 1. WEIGHT OF MILITARY DIVERS AFFECTED BY DECOMPRESSION SICKNESS FOR (1961–1966) AND 1968 PERIODS.



3.3.12 When the same comparison is made for civilian decompression cases during 1968, the weight factor under 150 occurs in 21.3% of the total civilian cases. This is due to the fact that a few female sports divers were given treatment. The intervals 191-210 and over 210 show appreciably larger percentages in comparison to the same weight categories for military divers. The sample of civilian cases is too small to be significant. If a larger sample were available, the information and findings would be more reliable.

3.3.13 Figure 2 compares the height of divers affected by decompression sickness for 1968 with the number of cases occurring during the 1961-1966 period. An approximately 60% increase in the 68-inch to 69-inch interval occurred during the 1968 period. An average of 70 inches held for both reporting periods. This average probably represents the average height of all military divers.

3.3.14 The height factor alone has very little or no relationship to the incidence of decompression sickness. However, when height is combined with weight, a ratio is obtained which applies to decompression sickness accidents.

3.3.15 Figure 3 compares the weight-to-height ratio of divers affected by decompression sickness during 1968 with similar incidents for the 1961-1966 period. A slight increase occurred in the average for the 1968 period, but no significant difference occurred within the specific values.

3.3.16 Table 9 shows the relationship between the outcome of the treatment and the weight-to-height ratio for the 54 cases reported for the 1968 period. The 2.40-2.59 category had the greatest number of cases. Since the mean of 2.52 falls within the 2.40 to 2.59 category the change is not significant.

FIGURE 2. HEIGHT OF DIVERS EXPERIENCING DECOMPRESSION SICKNESS FOR 1961–1966 AND 1968 PERIODS

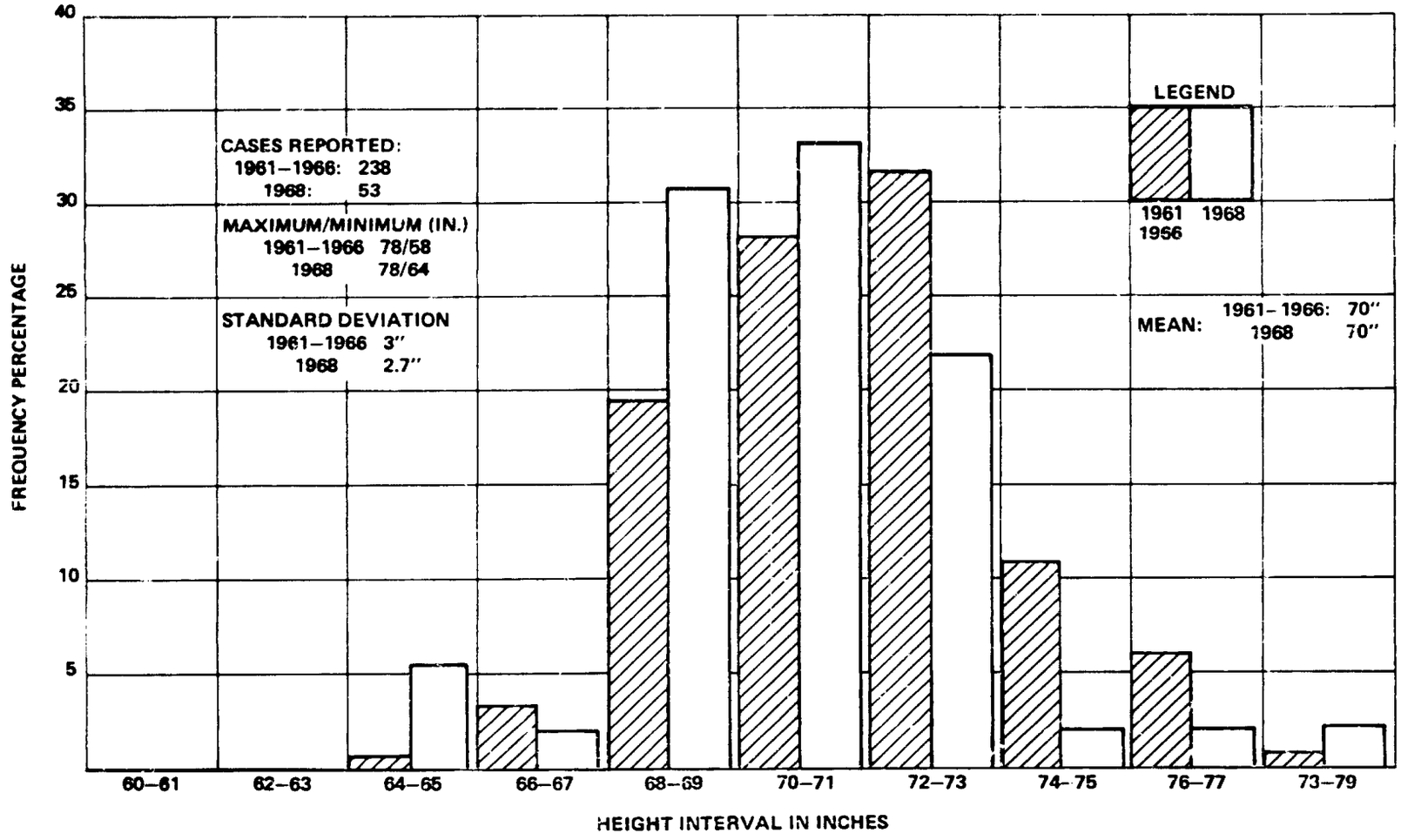


FIGURE 3. WEIGHT TO HEIGHT RATIO OF DIVERS EXPERIENCING DECOMPRESSION SICKNESS FOR 1961–1966 AND 1968 PERIODS.

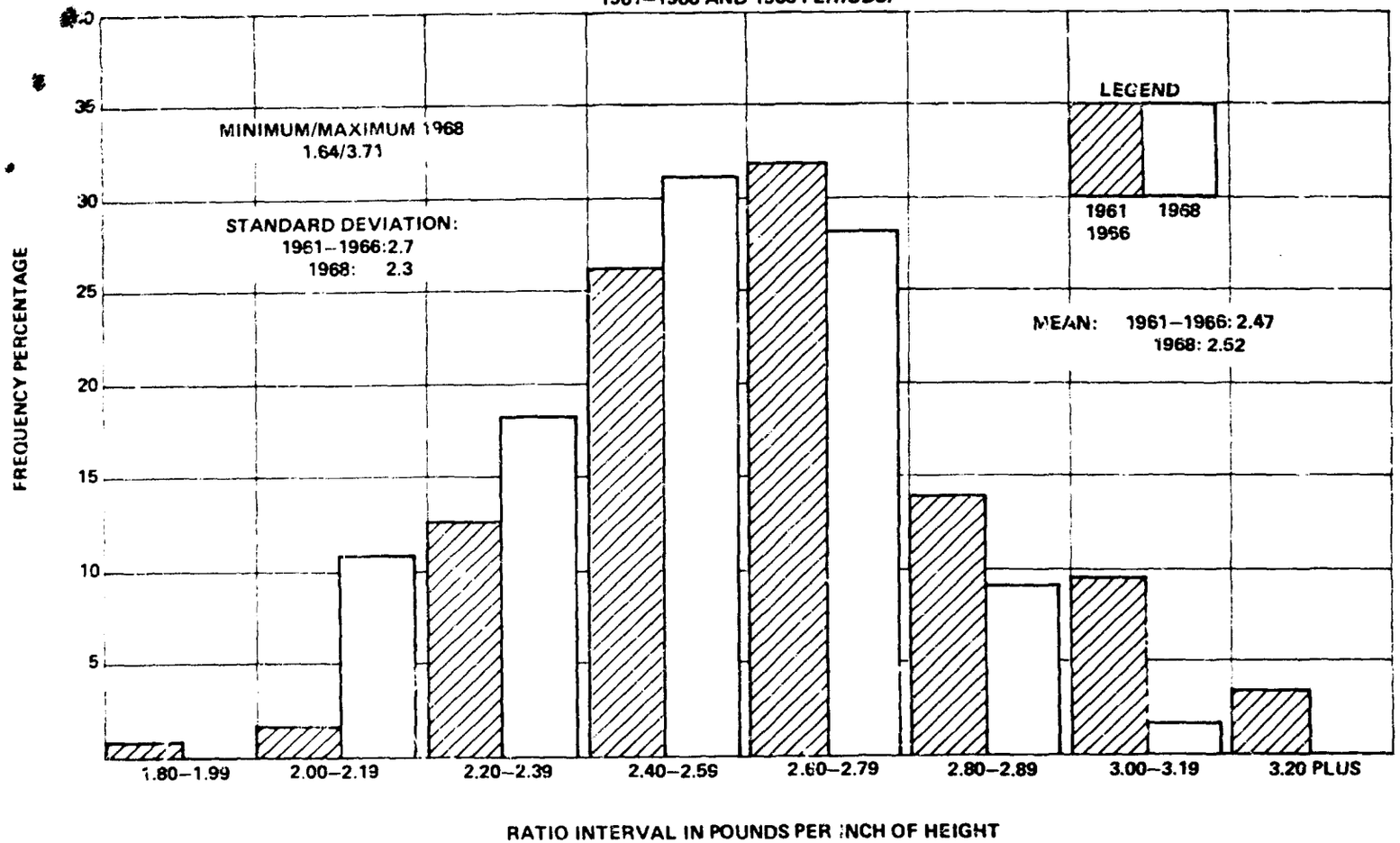


Table 9

Relationship Between Weight-to-Height Ratio of Divers Affected By Decompression Sickness and Outcome of Treatment for 1968

No. of Cases: 54

OUTCOME OF TREATMENT	WEIGHT TO HEIGHT RATIOS											
	2.00		2.20		2.40		2.60		2.80		3.00	
	Cases		Cases		Cases		Cases		Cases		Cases	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Complete Relief	4	66.7	10	100.0	16	94.1	10	66.7	3	60.0	1	100.0
Substantial Relief	2	33.3					3	20.0	1	20.0		
Residual Substancial					1	5.9						
Recurring Symptoms							2	13.3	1	20.0		
TOTAL CASES	6	100.0	10	100.0	17	100.0	15	100.0	5	100.0	1	100.0
PERCENT OF CASES	11.1		18.5		31.5		27.8		9.3		1.9	

3.4 OTHER FACTORS INVOLVED WITH DECOMPRESSION SICKNESS ACCIDENTS

3.4.1 Although the factors being reviewed in this portion of the report are not significant to the incidence of decompression sickness, they do suggest which personnel are most involved in accidents of this type. Table 10 shows the military service of personnel involved in decompression accident reports for 1968. Almost all cases occur in the U.S. Navy. There has been no significant difference from previous reports.

Table 10

Military Service of Personnel Affected by Decompression Sickness for the Reporting Periods 1961-1967 and 1968

MILITARY SERVICE	1961-1967 CASES		1968 CASES	
	Number	Percent	Number	Percent
U.S. Navy	274	96.5	53*	96.4
U.S. Air Force	7	2.4	1	1.8
U.S. Army	1	0.4	0	
U.S. Marines	2	0.7	0	
Foreign Nationals			1	1.8
TOTAL CASES	284	100.0	55	100.0

* Includes a Naval Aviator

3.4.2 Table 11 shows the qualifications for military divers during the reporting periods 1961-1967 and for 1968. Although it appears from the table that the number of officer personnel affected by decompression sickness has increased slightly for 1968, this is misleading. One of the three cases reported for 1968 involved a medical officer attending a patient undergoing hyperbaric oxygen therapy for gas gangrene. During 1968 none of the personnel affected was a Master Diver. This reflects the continued use of Master Divers in supervisory duties rather than actual diving duties. The reduction of the number of student personnel involved in decompression accidents may be due to a greater emphasis on safety factors and close supervision of training dives.

Table 11

Qualifications of Military Divers having Decompression Sickness for the Reporting Periods 1961-1967 and 1968

QUALIFICATION OF MILITARY DIVER	1961-1967 CASES		1968 CASES	
	Number	Percent	Number	Percent
Master Diver	15	5.5		
Diver First Class	166	60.4	39	73.5
Salvage Officer	1	0.4	0	
Diving Officer	14	5.1	3	5.7
Diver 2nd Class	23	8.4	1	1.9
UDT	11	4.0	1	1.9
EOD	4	1.4	0	
UWS	2	0.7	3	5.7
Submariner	2	0.7	2	3.8
Sports	9	3.3	0	
Marine Recon.	2	0.7	0	
Students	18	6.5	0	
Diving Medical Technician	8	2.9	4	7.5
TOTAL CASES	275	100.0	53	100.0

3.4.3 Table 12 shows the number and percentage of cases having a history of previous incidents of decompression sickness accidents. An increase in the number of cases showing no previous history of decompression sickness accidents occurred for the 1968 period.

Table 12

Cases in the 1961-1967 and 1968 Reporting Periods With History of Previous Decompression Accidents

NUMBER OF PREVIOUS ACCIDENTS	1961-1967 CASES		1968 CASES	
	Number	Percent	Number	Percent
None	190	70.1	32	60.4
One	61	22.5	11	20.7
Two	13	4.8	2	3.8
Three	2	0.7	4	7.5
Four	3	1.1	1	1.9
Five	1	0.4	3	5.7
Six	1	0.4		
TOTAL CASES	271	100.0	53	100.0

3.4.4 The trend toward multiple previous decompression accidents is particularly marked among those divers who are assigned to experimental diving duties. Table 13 shows that the largest category of military divers who experienced previous decompression incidents was engaged in experimental diving activities.

Table 13

Previous Decompression Accidents Related to Various Diving Activities Among Military Divers in 1968

No. of Cases: 53

NUMBER OF PREVIOUS ACCIDENTS	EXPERIMENTAL DIVES		MEDICAL TENDER DIVES		WORK DIVES		OTHER DIVES	
	Cases No.	%	Cases No.	%	Cases No.	%	Cases No.	%
None	16	48.5	2	100.0	10	71.4	4	100.0
One	7	21.2			4	28.6		
Two	2	6.1						
Three	4	12.1						
Four	1	3.0						
Five	3	9.0						
TOTAL CASES	33	100.0	2	100.0	14	100.0	4	100.0

3.5 DIVING FACTORS INVOLVED IN DECOMPRESSION SICKNESS DURING 1968.

3.5.1 Several diving analyses have been concerned with the impact of diving factors upon decompression sickness among divers. A few studies have established some correlation between diving factors and the frequency of decompression accidents. Information on dives which did not result in decompression accidents should be analyzed. Those diving factors which appear to have a positive correlation are those which involve the amount of work accomplished during a dive, the amount of bottom time, and the depth of a dive. Rivera's report, "Decompression Sickness Among Divers: An Analysis of 935 Cases" established some correlation in these areas.

3.5.2 There was a significant difference between the purpose of the dives during 1968 and similar data for the 1961-1967 period. Table 14 shows the totals and percentages for the purpose of the dive for those two periods. The experimental category showed a significant increase which was also noted in the 1967 report period. This increase of decompression sickness among divers engaged in experimental activity reflects the increased efforts to establish new deep diving procedures and techniques. No incidence of decompression sickness was reported for requalification dives during 1968. Only one case was reported for divers engaged in recreational diving.

Table 14

Incidence of Decompression Sickness Among Divers Engaged in Various Diving Purposes for the Reporting Periods 1961-1967 and 1968

PURPOSE OF DIVE	1961-1967 CASES		1968 CASES	
	Number	Percent	Number	Percent
Training	27	9.9	3	5.5
Selection	3	1.1	0	
Experimental	76	27.9	31	56.4
Requalification	19	7.0	0	
Working	109	40.1	16	29.1
Sport	7	2.6	1	1.8
Tender	28	10.3	2	3.6
Other	3	1.1	2	3 6
TOTAL CASES	272	100.0	55	100.0

3.5.3 Table 15 shows a significant increase of decompression sickness among divers in a wet pot diving environment. Decompression sickness reports for dives conducted in dry chamber and open water locations showed a decrease. The increase of wet pot dives reflects the use of this medium to conduct experimental diving.

Table 15

Incidence of Decompression Sickness in Various Types of Diving Media for the 1961-1967 and 1968 Reporting Periods

SITE OF DIVE	1961-1967 CASES		1968 CASES	
	Number	Percent	Number	Percent
Wet Pot	70	25.0	26	47.3
Dry Chamber	67	23.9	11	20.0
Escape Tank	4	1.4	0	
Altitude Exposure	4	1.4	2	3.6
Open Water	135	48.3	16	29.1
TOTAL CASES	280	100.0	55	100.0

3.5.4 A significant percentage change appears in the use of open-circuit diving apparatus during 1968. This type of diving rig is used in experimental diving. Table 16 shows the percentage rate of decompression sickness accidents for various types of diving apparatus. Deep sea air dives decreased substantially. This decrease continues the trend in this type of dive established during the previous 1967 reporting period. A majority of the experimental dives were made with open-circuit apparatus.

Table 16

Decompression Sickness Incidents Reported in 1961-1967 and 1968 Among Divers Using Various Types of Diving Apparatus

DIVING APPARATUS	1961-1967 CASES		1968 CASES	
	Number	Percent	Number	Percent
APP Buoyant Ascent	3	1.1	0	
Shallow Water Mask	9	3.4	1	1.8
Hookah	4	1.5	4	7.4
Deep Sea Air	77	28.7	10	18.5
Deep Sea HeO_2	22	8.2	1	1.8
Chamber Dive	60	22.4	9	16.7
Altitude Chamber	4	1.5	2*	3.7
Closed Circuit SCUBA	7	2.6	0	
Semi-Closed SCUBA	15	5.6	10**	18.5
Open Circuit	67	25.0	17	31.6
TOTAL CASES	268	100.0	54	100.0

* Includes one case of aircraft decompression sickness
** Includes three cases using MK 6 Semi-Closed SCUBA apparatus

3.5.5 Table 17 shows an increase in types of breathing media used during the 1968 reporting period. The open circuit Helium-Oxygen mixture used in experimental diving activitites accounts for the largest single item of change. The percentage drop in decompression cases using air as a breathing medium continued the trend from the 1967 reporting period. The two cases of decompression sickness using oxygen involved flying personnel, one in an altitude chamber, the other in actual flight operations. The two dives using Helium-Nitrogen-Oxygen gas mixture involved diving depths of 600 and 1000 feet, respectively.

Table 17

Types of Breathing Media Used in Incidences of Decompression Sickness for the Reporting Periods 1961-1967 and 1968

BREATHING MEDIUM	1961-1967 CASES		1968 CASES	
	Number	Percent	Number	Percent
Air	190	69.4	22	40.0
Helium-Oxygen Mix	61	22.3	26	47.3
Nitrogen-Oxygen Mix	2	0.7	3	5.5
HeO_2N_2	16	5.8	2	3.6
Air and Oxygen	5	1.8	2	3.6
TOTAL CASES	274	100.0	55	100.0

3.5.6 Table 18 shows the number of dives made during the previous 12-hour period during the 1961-1967 and the 1968 periods. An increase is found for those personnel making two dives during the 1968 period. Of the six cases making more than one dive, four cases were making a work dive; the other two were involved in recreational and experimental diving activities.

Table 18

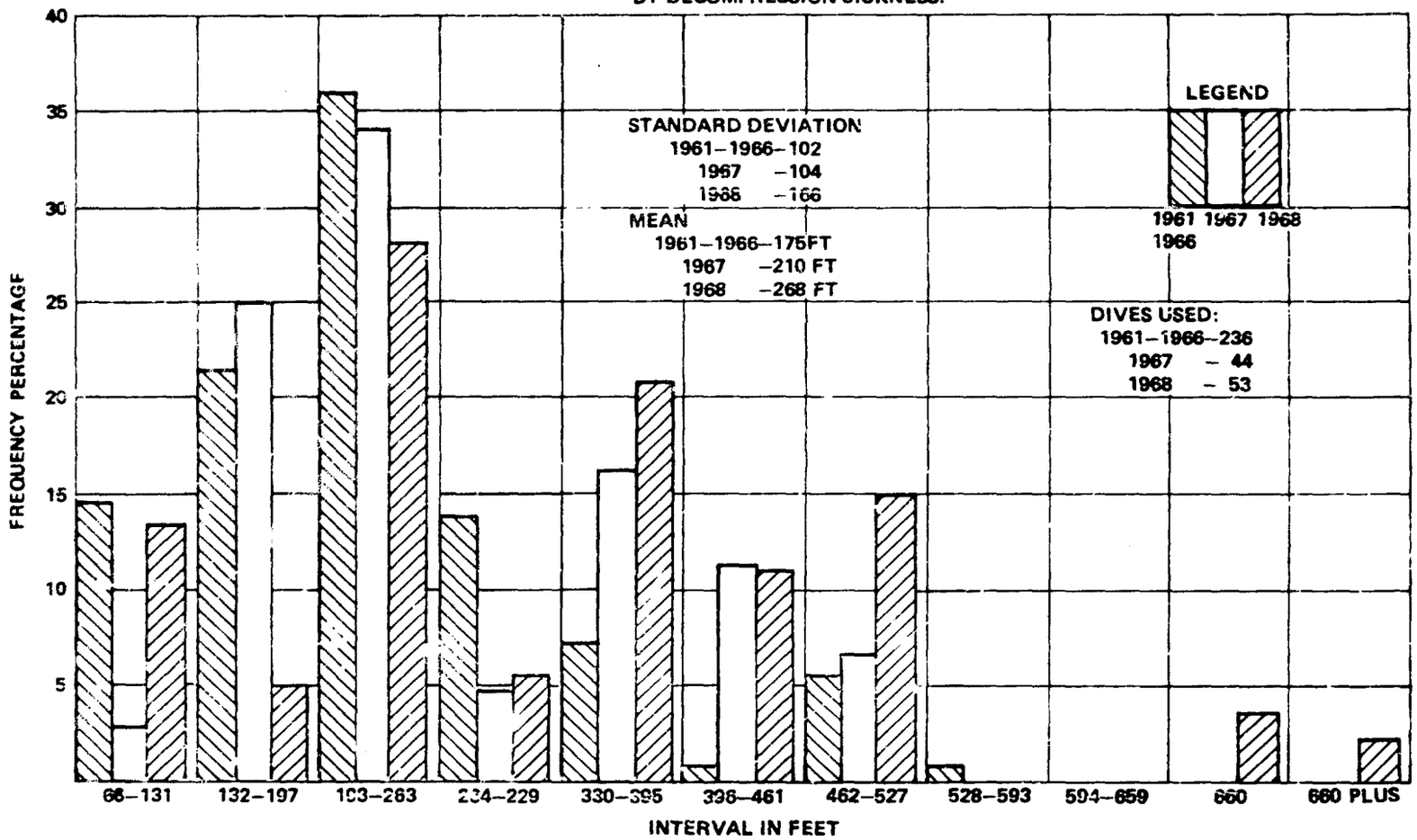
Number of Dives Made Within 12 hours Preceding a Decompression Accident for the 1961-1967 and the 1968 Reporting Periods for Military Divers

NUMBER OF DIVES WITHIN 12 HOURS	1961-1967 CASES		1968 CASES	
	Number	Percent	Number	Percent
One	246	87.8	47	88.7
Two	17	6.1	5	9.4
Three	12	4.3	0	
Four	4	1.4	1	1.9
Five	0		0	
Six	1	0.4	0	
TOTAL CASES	280	100.0	53	100.0

3.5.7 Figure 4 shows the depth of the first dive made by military divers affected by decompression sickness during the 1961-1966, 1967, and 1968 periods. A comparison between the three periods shows a steady increase in the mean depths of the first dive. For 1961-1966 the mean depth was 175 feet; 1967 mean depth was 210 feet; and for 1968 the mean depth was 268 feet. The difference between the 1961-1965 and the 1968 periods is a 65% increase in the mean depth of the first dive. One decompression accident reported during 1968 involved a dive of 1000 feet. In the future the trend toward deeper diving depths will continue due to experimental diving efforts.

3.5.8 During 1968 there was a significant change in the pattern of bottom times of dives which resulted in decompression sickness. Figure 5 shows a comparison in percentage of incidents for the reporting periods 1961-1966, 1967, and 1968. It is noted that in comparing the 1968 period with other periods, the bottom time within the 51 to 60-minute and more than 60-minute range increased significantly. The majority of dives conducted with greater bottom times involved only one dive. Almost all of the dives were

FIGURE 4. DEPTH OF FIRST DIVE FOR 1961–1966; 1967; AND 1968 PERIODS FOR DIVERS AFFECTED BY DECOMPRESSION SICKNESS.



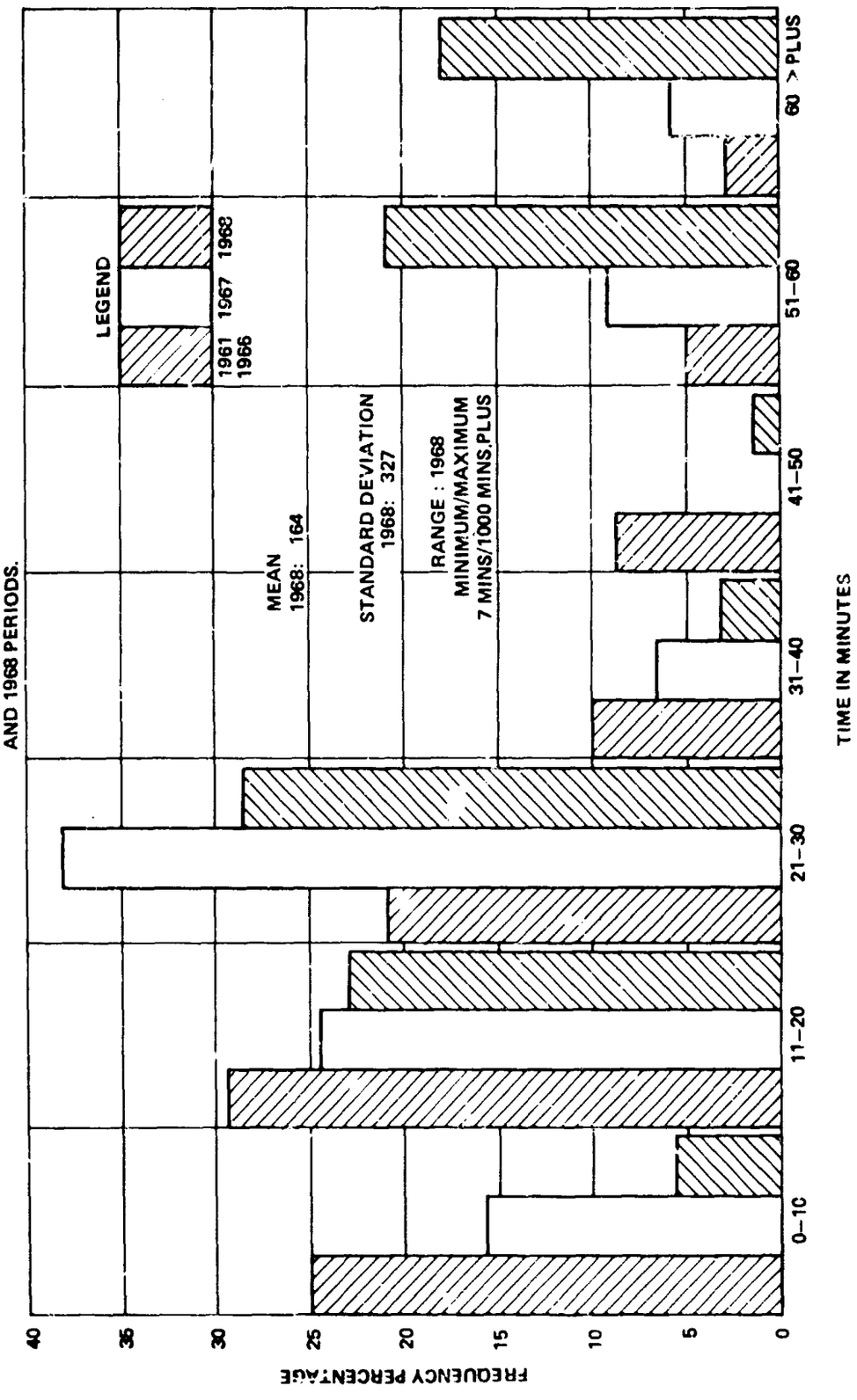


FIGURE 5. BOTTOM TIME OF FIRST DIVE RESULTING IN DECOMPRESSION SICKNESS AMONG MILITARY DIVERS FOR 1961–1966; 1967; AND 1968 PERIODS.

experimental types. Three dives of 10 minutes or less of bottom time resulted in decompression sickness during 1968. Two of these dives were dry chamber runs; the other dive was made using a deep sea helium apparatus. Table 19 shows a comparison in numbers and percentages among the three reporting periods.

Table 19

Bottom Times of Dives Resulting in Bends for the Reporting Periods 1961-1966, 1967, and 1968

BOTTOM TIME IN MINUTES	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
10	52	25.0	7	15.5	3	5.7
20	60	28.9	11	24.5	12	22.6
30	44	21.2	17	37.8	15	28.3
40	20	9.6	3	6.7	2	3.8
50	16	7.7	0		1	1.9
60	10	4.8	4	8.8	11	20.8
60+	6	2.8	3	6.7	9	16.9
TOTAL CASES	208	100.0	45	100.0	53	100.0

3.5.9 During the 1968 reporting period there was a significant change in the types of work conducted by divers affected by decompression sickness. Table 20 shows a comparison among the 1961-1966, 1967, and 1968 report periods. Over 90% of the cases were reported as engaged in mild and moderate work for the 1968 period. For the 1967 period approximately 76% of the divers were engaged in moderate and heavy work. The majority of divers engaged in moderate work were involved in experimental diving. The second largest category of divers engaged in moderate work were those involved in working dives.

Table 20

Types of Work Engaged in by Divers Affected by Decompression Sickness for the Reporting Periods 1961-1966, 1967, and 1968.

TYPE OF WORK	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
Mild	37	23.0	9	23.7	10	21.8
Moderate	71	44.1	19	50.0	33	71.7
Heavy	53	32.9	10	26.3	3	6.5
TOTAL CASES	161	100.0	38	100.0	46	100.0

3.5.10 The significance of the change in type of work and the incidence of decompression sickness cannot be determined. It is assumed that divers engaged in heavy work are more likely to be affected by decompression sickness. The heavy work category has declined over the period, probably because of the increased emphasis on experimental dives which usually do not involve heavy work. Exertion during and after diving remains an important factor to be considered. Also, to achieve a comprehensive view of the impact of work upon decompression sickness, the type of work being done by all divers must be known.

3.6 TREATMENT OF DECOMPRESSION ACCIDENTS

3.6.1 This portion of the report is concerned with the decompression accident and its treatment. The information presented here is derived from fifteen variables which are included on the accident report. Six of the variables describe the location, intensity, time of onset of symptoms, and the nature of the decompression sickness accident. The remainder of the variables deal with the type, timing, and the result of the treatment.

3.6.2 The relationships among these variables are more tenuous than the relationships of age, weight, and height described in the previous section. To identify those variables that have a more positive correlation with decompression sickness therapy requires a comparison with data from the fleet diving log forms. The information in this portion of the report is presented to encourage reporting activities to prepare as complete an accident report as possible. Although the present accident report presents much pertinent information, reporting activities are encouraged to submit additional information, which may be of value. Of particular interest is the final outcome of the case: changes in the patient's condition which are not now being reported; the attending physician's concept of the cause of the accident; or the unusual circumstances surrounding the dive; such as the amount of exercise or work the diver was engaged in prior to, during, and after the dive.

3.6.3 Table 21 shows the time of onset of decompression sickness symptoms after a dive. The data for the reporting period 1968 is compared with the same data from Lt. Rivera's report prepared during 1963 and with the 1961-1966 and 1967 reporting periods. Since 1963, there has been an increase in the experimental diving activities. During the same period there has also been a gradual overall increase in the number and percent of divers reporting symptoms during a dive. In the 1968 reporting period, a very large increase is shown in Table 21 for divers reporting symptoms during a dive.

Table 21

Cumulative Percentages of Decompression Accident Cases Reporting Symptoms During Dives and After Dives

TIME AFTER DIVE	1963* CASES Cumulative Percent	1961-1966 CASES Cumulative Percent	1967 CASES Cumulative Percent	1968 CASES Cumulative Percent
	ONSET OF SYMPTOMS DURING DIVES			
	9.1	12	11	45
MINUTES	ONSET OF SYMPTOMS AFTER DIVES			
20		40	41	58
40		50	56	66
60	54.7	56	59	72
80		60	59	72
100		61	67	74
120	66.8	65	69	74
140		66	74	74
160		68	79	78
180		71	82	82
240		78	85	82
300		84	87	84
360	88.2	90	90	88
400		93	95	93
400 Plus		100	100	100

* 1963 entries are taken from Lt. Rivera's report.

3.6.4 Table 21 shows a large increase in the percentage of cases reporting symptoms during the dive for the 1968 reporting period. In addition, a substantial percentage increase is also noted for onset of symptoms during the first hour after a dive. The average depth of dive for 23 cases in which symptoms were reported under pressure was 377 feet. Over 95% of these cases were engaged in experimental dives, and approximately 70% were in a "Wet Pot Dive".

3.6.5 The most common symptom reported during 1968 was localized pain. Table 22 shows the various symptoms reported with a comparison between the various reporting periods. For the 1968 period a decrease is noted for the percentage of cases reporting localized pain as compared to the 1961-1966 and 1967 periods. The greatest single percentage increase is noted for cases reporting symptoms of paresthesia. A survey of the breathing medium used by the divers displaying this symptom revealed 5 cases used air as a breathing medium; three cases used HeO_2 and two cases were on pure oxygen. The only two cases reported during 1968 in which decompression sickness was attributable to altitude exposure displayed paresthesia as a symptom. Only one case involved a diver engaged in experimental type diving while seven of the divers affected were engaged in working type dives. Since cases of massive decompression sickness did not occur during 1968, no incidence of paralysis and unconsciousness was noted. Increases in cases of nausea, restlessness, and visual disturbances cannot be explained. These differences may be due to incomplete reporting procedures by the personnel attending the patients, or due to a preoccupation with a more severe symptom by either the attending medical official or the diver during previous report periods.

Table 22

Various Signs or Symptoms Displayed in Decompression Sickness Accidents During 1968.

SIGN OR SYMPTOM	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
Localized Pain	236	99.2	47	100.0	46	83.6
Rash	32	13.4	6	12.8	8	14.5
Muscular Weakness	43	18.1	14	29.8	7	12.7
Numbness	38	16.0	9	19.1	7	12.7
Dizziness	17	7.1	5	10.6	7	12.7
Visual Disturbances	13	5.5	3	6.4	7	12.7
Paralysis	2	0.8	2	4.3	0	
Unconsciousness	2	0.8	2	4.3	0	
Dyspnea	4	1.7	0		0	
Nausea	11	4.6	0		5	9.1
Muscular Twitching	1	0.4	0		1	1.8
Restlessness	1	0.4	0		3	5.5
Convulsions	0		1	2.1	0	
Acoustic Aura	1	0.4	1	2.1	1	1.8
Paresthesia	12	5.0	1	2.1	10	18 2
Itching	0		2	4.3	0	
TOTAL CASES*	238		47		55	

* NOTE: More than one type of symptom may be reported for a single case.

3.6.6 Table 23 shows the number and percentage of organ systems involved in decompression accident cases during 1968. The 1968 cases are compared with similar cases which occurred during the 1961-1966 and 1967 reporting periods. There were no significant differences noted in comparison among the three periods except in the skin bends category. The divers who displayed this type of symptom during the 1968 reporting period were using either air or HeO_2 as a breathing medium. In five out of eight cases, the dive took place in a "wet pot." Most of these dives were experimental. Since none of the decompression cases occurring during 1968 resulted in a fatality, there was a concomitant reduction in central nervous system symptoms percentages in 1968.

Table 23

Organ Systems Involved in Decompression Accident Cases During 1968.

ORGAN SYSTEM	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
Musculoskeletal Pain	197	82.8	41	89.1	45	81.8
CNS Motor	28	11.8	13	28.3	7	12.7
CNS Sensory	42	17.6	13	28.3	13	23.6
CNS Spl. Sense	18	7.6	5	10.9	7	12.7
CNS Convulsion	0		1	2.2	0	
CNS Unconsciousness	4	1.7	3	6.5	0	
Skin Bends	31	13.0	4	8.7	8	14.5
Respiratory	4	1.7	2	4.3	0	
Generalized	8	3.4	3	6.5	8	14.5
TOTAL CASES*	238		46		55	

NOTE: More than one organ system may be involved in a single case.

3.6.7 Table 24 shows the locations of symptoms are compared for the 1961-1966, 1967, and 1968 reporting periods. In comparing the locations of symptoms no significant change is apparent. The largest single trauma was knee pain. The average depth of water for the 21 cases reporting this type of symptom was approximately 340 feet. Eleven of the 21 cases involved "wet pot" dives; 18 of the 21 cases were involved in experimental diving. Since a majority of the divers were in experimental activities and used HeO_2 as a breathing medium, these findings may be relevant to the incidence of knee pains. The next largest category of symptoms was shoulder pains. Average depth of dive for personnel experiencing shoulder pain was 270 feet. Ten of the 15 cases reporting shoulder pains used oxygen. Thirteen cases were conducted in either a wet pot or in open water. One dive was in a dry chamber and the other involved an altitude chamber. Some correlation seems to exist between the site of the trauma and the depth of water.

Table 24

Location of Signs or Symptoms of Decompression Sickness Accidents

LOCATION OF SIGN OR SYMPTOM	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
Generalized	37	15.5	6	12.8	16	29.1
Left Side	6	2.5	0		2	3.6
Right Side	4	1.7	5	10.6	1	1.8
Upper Half	9	3.8	3	.4	0	
Lower Half	2	0.8	0		0	
Extremities	10	4.2	3	6.4	1	1.8
Head	3	.3	0		1	1.8
Eye	6	2.5	4	8.5	6	10.9
Ear	2	0.8	2	.3	3	5.4
Nose	0		2	4.3	0	

Table 24 (Continued)

Location of Signs or Symptoms of Decompression Sickness Accidents

LOCATION OF SIGN OR SYMPTOM	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
Face	7	2.9	0		0	
Neck	7	2.9	0		1	1.8
Shoulder	53	22.3	9	19.1	15	27.3
Arm	24	10.1	2	4.3	0	
Upper Arm	16	6.7	2	4.3	5	9.1
Elbow	40	16.8	5	10.6	5	9.1
Forearm	7	2.9	4	8.5	8	14.5
Wrist	9	3.8	6	12.8	2	3.6
Hand	29	12.2	2	4.3	5	9.1
Fingers	7	2.9	2	4.3	3	5.4
Chest	11	4.6	4	8.5	0	
Upper Back	11	4.6	1	2.1	3	5.4
Lower Back	11	4.6	3	6.4	3	5.4
Abdomen	9	3.8	1	2.1	3	5.4
Buttocks	3	1.3	1	2.1	3	5.4
Groin	5	2.1	0		1	1.8
Hip	9	3.8	0		3	5.4
Leg	21	8.7	7	14.9	10	18.2
Thigh	4	1.7	3	6.4	2	3.6
Knee	54	22.7	17	36.2	22	40.0
Calf	4	1.7	0		1	1.8
Ankle	13	5.5	0		4	7.3
Foot	6	2.5	0		2	3.6
TOTAL CASES	238		47		55	

NOTE: More than one sign or symptom may be involved in a single case.

3.6.8 Table 25 shows a comparison between the 1968 report period and the reporting periods of 1961-1966 and 1967 for contributing factors to decompression accidents. The sample being reviewed is too small to be relevant. The reporting of contributing factors that would adversely reflect upon the procedure used during a dive tends to reduce the reporting of such factors.

Table 25

Decompression Accidents Attributed to Various Contributing Factors for the Reporting Periods 1961-1966, 1967, and 1968.

CONTRIBUTING FACTORS	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
Equipment Failure	0		0		0	
Human-Equip. Failure	0		0		0	
Human Procedural Failure	27	13.3	6	26.1	3	33.3
Contributing Environmental Factor	99	48.8	9	39.1	0	
Human Physical	77	37.9	8	34.8	6	66.7
TOTAL CASES	203	100.0	23	100.0	9	100.0

3.6.9 Compared to civilian cases, decompression accident cases which involve military divers have a much shorter delay period between the onset of the symptom and the treatment. The amount of time between the onset of the symptom and the start of treatment has been found to be crucial in determining the patient's response, especially in serious cases of decompression sickness involving the spinal cord. Lt. Rivera's report (23) found that, in general, the longer the delay in treatment, the poorer the outcome of the case.

Table 26 shows a comparison between the onset of the symptoms and start of the treatment for the present 1968 report and the two previous periods. Although there was a general tendency for a higher proportion of the 1967 cases to be treated earlier than previous periods, the 1968 period shows a reverse in this trend. Eight cases reported during 1968 had a delay period of over 5 hours between onset of symptoms and start of treatment. Three cases had substantial relief after treatment; none of the cases had recurring symptoms. A review of the eight cases reveals no significant factors. Those divers who were involved in experimental type dives were treated with longer decompression time than divers involved in work or sport diving. Four divers involved in experimental diving were subjected to an average depth of 310 feet and subsequently were given treatment which averaged 785 minutes. The other four cases involved either training, sport, or working dives. The average depth attained by these divers was 154 feet. Decompression time averaged 40 minutes.

Table 26

Delay Between Onset of Symptoms and Start of Treatment for 1961-1966, 1967, and 1968 Reporting Periods

DELAY BETWEEN ONSET AND TREATMENT	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Cumulative Percent	Number	Cumulative Percent	Number	Cumulative Percent
20 Minutes	62	28.6	16	39.0	16	30.1
40 Minutes	27	41.0	6	53.7	3	35.8
60 Minutes	19	49.7	5	65.9	9	52.8
2 Hours	37	66.9	3	73.2	9	69.8
3 Hours	17	74 8	4	82.9	6	81.1
5 Hours	19	83.4	4	92.9	2	84.9
SUB-TOTALS	181		38		45	
75 Hours	30	100.0	3	100.0	8	100.0
TOTAL CASES	211		41		53	

3.6.10 Table 27 shows a comparison between the cases experiencing full relief at specified depths of the three time periods. Most of the cases were relieved at less than 66 feet. A slight increase is noted for the 1968 period for the percent of divers subjected to recompression depths of over 99 feet. A survey of these cases revealed no significant difference in reference to the location of the trauma or the diver's age and weight.

Table 27

Cases Experiencing Full Relief at Various Depths for the 1961-1966, 1967, and 1968 Reporting Periods

DEPTH OF FULL RELIEF	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Cumulative Percent	Number	Cumulative Percent	Number	Cumulative Percent
0-33 Feet	43	19.5	2	4.4	3	5.7
34-66 Feet	89	59.7	27	64.4	30	62.3
67-99 Feet	16	67.0	3	71.1	6	73.6
100-132 Feet	26	78.7	2	75.6	4	81.1
133-165 Feet	38	95.9	4	84.4	4	88.7
Over 165 Feet	0	95.9	1	86.7	1	90.6
Sub-Total Full Relief	212		39		48	
No Relief	9	100.0	6	100.0	5	100.0
TOTAL CASES	221		45		53	

3.6.11 Table 28 shows a comparison between the number and percentage of cases in 1968 experiencing full relief within a specified period of time and the cases reported in 1961-1966 and 1967. A review of the three periods shows a slight decrease in the trend of divers experiencing relief within one hour. An increase in the trend is noted for the time period of over one hour. This may be due to the increase in the depths of dives. A review of the 12 cases, which experienced relief in over 60 minutes, revealed that the average age of these cases coincided with the average age of all divers affected by decompression sickness.

Table 28

Cases Experiencing Full Relief
Within a Specified Period of Time

MINUTES FOR FULL RELIEF	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Cumulative Percent	Number	Cumulative Percent	Number	Cumulative Percent
0-10	149	67.7	27	61.4	29	53.7
11-20	28	80.5	5	72.7	6	64.8
21-30	14	86.8	2	77.3	2	68.5
31-40	4	88.6	1	79.5	4	75.9
41-50	6	91.4	0	79.5	1	77.8
51-60	1	91.8	0	79.5	1	79.6
61-70	2	92.7	0	79.5	1	81.4
71-80	1	93.2	1	81.8	1	83.3
81-90	0	93.2	0	81.8	0	83.3
91-100	0	93.2	0	81.8	1	85.1
101 Plus	6	95.0	2	86.4	2	88.8
SUB-TOTALS FULL RELIEF CASES	211		39		48	
No Relief Cases	9	100.0	6	100.0	6	100.0
TOTAL CASES	220		44		54	

3.6.12 During 1968 two cases reported symptoms of skin "bends." These symptoms occurred approximately 2 hours after completion of the dive. Although this symptom may be a precursor of more serious symptoms, oxygen therapy was the only treatment prescribed.

3.6.13 Table 29 shows a breakdown of the type of treatment used in the therapy of decompression accident cases for the three reporting periods: 1961-1966, 1967, and 1968. Significant increases are noted in the "Table 6" and "Other Treatment" categories.

Table 29

Type of Treatment Used for Cases of Decompression Sickness for the Reporting Periods 1961-1966, 1967, and 1968.

TYPE OF TREATMENT	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
Table 1	57	24.4	3	6.5	2	3.6
Table 1A	5	2.1	2	4.3	1	1.8
Table 1 Modified	1	0.4	1	2.2	0	
Table 2	59	25.2	6	13.0	2	3.6
Table 2A	1	0.4	0		0	
Table 2 Modified	4	1.7	0		0	
Table 3 (Air)	13	5.6	0		0	
Table 3 (Ox.)	10	4.3	2	4.3	2	3.6
Table 3 Modified	9	3.8	2	4.3	4	7.3
Table 4 (Air	6	2.6	2	4.3	0	
Table 4 (Ox.)	1	0.4	0		0	
Table 4 (HeO_2)	1	0.4	0		0	
Table 4 Modified	6	2.6	0		0	
Table 5	10	4.3	15	32.6	10	18.2
Table 6	5	2.1	6	13.0	14	25.5
Table 5 or 6 Modified	28	12.0	4	8.7	5	9.1
O_2 on Surface	10	4.3	1	2.2	2	3.6
Standard Decom. Schedule	0		0		0	
Other Treatment	8	3.4	2	4.3	13	23.6
TOTAL CASES	234	100.0	46	99.7	55	99.9

3.6.14 Thirteen cases were treated during 1968 with "other treatment" therapy. All involved experimental dives. The first symtoms were noticed during the decompression phase and were usually treated by recompressing the diver and changing to an oxygen rich gas mixture. One case involved a diver who developed symptoms in his left forearm and wrist after having been subjected to venal blood sampling. The symptom occurred at 95 feet during decompression and became progressively worse at 75 feet. The patient was given 60% oxygen and the original decompression schedule was continued. At 65 feet the patient was asymptomatic. In all thirteen cases, the patients obtained complete relief. The excellent response to therapy may be due to the fact that a medical doctor treated all cases and the treatment was tailored to fit the circumstances.

3.6.15 Four cases in 1968 were treated using modified tables. Three of these cases had recurring symptoms after initial treatment. All patients were brought to normal surface pressure using Table 3, 5, or 6. Two cases were working type dives from the same diving activity. These cases will be summarized in the following section.

3.6.16 As shown in Table 30, the percentage of cases treated by medical doctors increased by 5% over the previous two reporting periods. This trend will probably increase, since experimental dives to greater depths and with various gas mixtures are increasing. These require the attendance of a medical doctor for fast reactions to emergency conditions.

Table 30

Decompression Accident Cases Treated by Specific Types of Personnel

INDIVIDUAL TREATING THE CASE	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
U.S.N. Doctor	175	74.5	34	75.5	44	80.0
U.S.N. Corpsman	49	20.8	8	17.8	11	20.0
Master Diver	6	2.6	3	6.7		
Military Doctor	1	0.4				
Diver Treated Himself	1	0.4				
Civil Doctor	3	1.3				
TOTAL CASES	235	100.0	45	100.0	55	100.0

3.6.17 Table 31 shows the outcome of the treatment given to decompression cases for the report periods 1961-1966, 1967, and 1968. No fatalities involving decompression accidents occurred among military divers during 1968. Four cases involved patients who displayed residual symptoms after the initial treatment. The residual symptoms in these cases were not severe and were eventually resolved. A short summary of the four cases is given in the following paragraphs.

Table 31

Outcome of the Treatment for Decompression Accident Cases

OUTCOME OF TREATMENT	1961-1966 CASES		1967 CASES		1968 CASES	
	Number	Percent	Number	Percent	Number	Percent
Relief Complete	189	79.4	36	78.3	43	79.6
Relief Substantial	20	8.4	1	2.2	7	13.0
Residual Substantial	6	2.5	1	2.2	1	1.9
Fatal	0		3	6.5	0	
Recurring Symptoms Under Pressure	12	5.0	1	2.2	0	
Recurring Symptoms on Surface	11	4.6	4	8.7	3	5.5
TOTAL CASES	238	99.9	46	100.1	54	100.0

Section 4

CASE REPORT

4.1 INTRODUCTION

4.1.1 This section of the report will review an unusual incident of decompression sickness that involved eight divers from the same diving activity. Six of the eight divers involved in a working requalification dive developed decompression sickness, although the circumstances surrounding the dives cannot be considered unusual or particularly conducive to the accident.

4.1.2 A review of this case was conducted by the medical personnel attending the case, various Navy Commands, and the Experimental Diving Unit. The findings are inconclusive and the cause or reasons for the accident cannot be definitely identified. A more detailed analysis is being made by the Naval Safety Center, Norfolk, Va., in an attempt to establish the cause of this multiple accident. At the present time the results of this analysis have not been published.

4.2 CASE REPORT

4.2.1 Decompression Sickness Accident, 11 July 1968. EDU File Numbers: (3935 through 3936). Depth of Dives: 149 feet; Bottom Time: 30 minutes; Breathing Medium: Air; Diving Rig Used: Deep Sea Hard Hat; Decompression Schedule: 150/30.

4.2.1.1 On 11 July 1968, between 1745 and 2315 hours, five divers on an ASR involved in identical dives reported symptoms of decompression sickness. The first two cases were placed in the ASR's recompression chamber and treated under Table 3. The ship immediately got underway and started to return to port.

4.2.1.2 During the trip back to port, another diver developed symptoms of decompression sickness. This diver was given oxygen by mask and recompressed to the depth at which the other two divers were being treated. The three patients were being tended by one of the group of divers who had also made the same dives involved in this case. Therefore he underwent recompression with the patients. This diver did not report or show symptoms of decompression sickness. By 2100 hours all three divers reported that they were free of symptoms.

4.2.1.3 During the period that the three divers in the recompression chamber were being treated, the remaining four divers were placed under observation and given oxygen on the surface as a propylactic.

4.2.1.4 After the vessel reached port, two of the divers who had been receiving oxygen on the surface reported symptoms of decompression sickness. These divers were transferred to other recompression facilities and treated with Table 6. The remaining two divers were granted liberty at 0800 hours the next morning. By 1400 hours, all five divers who had undergone recompression were discharged as free of symptoms.

4.2.1.5 Between 1750 and 1820 hours, the three divers who had originally been treated in the ASR's recompression chamber under Table 3, reported recurring symptoms of decompression sickness. These patients were recompressed for a second time and treated under Table 6. By 2251 hours this recompression schedule was completed. One diver complained of weakness in his left leg. This symptom was treated with additional recompression to 30 feet and brought out under Table 5. Upon completion of treatment, no further symptoms developed and the patient was discharged.

4.2.1.6 At 2200 hours, 12 July, one of the divers who had been granted liberty, was reported under arrest for intoxication and assault. The prisoner's behavior was so unusual that a detention officer called the ship to report the prisoner's condition and actions. Upon examination by a medical officer, the prisoner was diagnosed as suffering from decompression sickness and was immediately transferred to a recompression facility. Recompression was started and the patient was treated under Table 6. Within a short time all symptoms disappeared and complete recovery was made within 5 hours.

4.2.1.7 The following presents a number of factors involved in this accident.

a. Background Factors:

1. On the two days prior to the accident, seven of the divers were involved in training and requalification dives. The breathing medium for these dives was HeO_2, bottom time 10 minutes, and depth of dive 210 feet. Except for one incident of minor ear trouble, all divers performed these dives without incident.

2. Prior to and during the training and requalification dives, the divers were engaged in heavy work that involved placing ship moorings and other work on the ASR. On the day of the accident, the divers had received approximately 5 hours of sleep.

b. Post Accident Investigation and Findings:

1. The three divers who were treated aboard the ASR on Table 3 or a modified Table 6 subsequently developed recurring symptoms that were cleared up when retreated on Table 6.

2. The one diver of the group who had not participated in the HeO_2 training and requalification dives, did not develop symptoms of decompression sickness.

3. One diver who acted as tender to the three cases on the ASR did not develop symptoms of decompression sickness. This diver may have developed symptoms if he had not undergone some recompression while acting as tender.

4. The three divers who were initially treated under Table 6 (using air and oxygen) did not develop recurring symptoms.

5. An analysis of the air banks on-board the ASR found that the gas mixture was free of foreign matter and contained no evidence of toxic agents.

6. The depth gauges were calibrated by two facilities; one facility found a mean error of approximately 2.5 feet, the other found an error of only 0.1 percent. However, the calibrations conducted of the depth pneumofathometers did not duplicate the environmental conditions of the dive site. The divers may have momentarily exceeded the 150-foot depth during the dive. Since the divers were to the limits of depth and bottom time for the decompression schedule used, this may have been a factor. However, the safety factor inherent in the decompression schedules should have provided a sufficient margin of safety to counteract the slight differences in the known dive depth. In addition, the expected failure rate for decompression tables, with all other factors being equal, is approximately 0.5 of 1.0 percent.

7. The combination of HeO_2 dives made on the previous two days, the heavy work schedules followed by the divers, and the long duration and depth of the dive for the decompression schedule used may be contributing factors to this accident. However, the HeO_2 dives and the diving limits of the dive resulting in the accident were within prescribed limits outlined by the Navy Diving Manual.

4.5 DISCUSSION

4.3.1 Although recommendations were made to comprehensively review and analyze this accident, the resources and manpower to be applied would have delayed other vital diving projects. In addition, the effort required to duplicate the entire sequence leading up to and during the accident would not be feasible. Since conditions cannot be duplicated with any degree of accuracy, any data derived from this effort would not be relevant to the accident.

4.3.2 To gain a degree of objectivity in accident investigations, it was recommended that the Navy Safety Center, Norfolk, Va., conduct a comprehensive review and analysis of this accident.

4.3.3 Although the cause of this accident and other accidents that occur to diver may not be identified, the need to develop means of disseminating information concerning accidents to all diving facilities is required. Information on accidents could result in reducing accidents of all types and enable diving personnel to become more cognizant of better working procedures, diving safety advances, and techniques in the treatment of accident cases.

4.3.4 This decompression accident involved many factors that are impossible to define or identify at this stage. Although many of the factors have some correlation to decompression accidents, their impact upon this accident cannot be specifically determined. Since many of the work routines used by the personnel involved were not described, it is possible that these had a greater relevancy to the accident than the factors now being discussed and evaluated.

Appendices

APPENDIX A

RIVERA EDU RESEARCH REPORT 1-63

SUMMARY

Problem:

To analyze 935 cases of decompression sickness among divers, and to determine the effectiveness of the U. S. Navy Treatment Tables for decompression sickness

Procedure:

All decompression sickness reports on file at the Experimental Diving Unit were analyzed and coded in the Diving Casualty Data Card. The reporting period included the years 1946-1961.

Findings:

(1) Two out of every ten divers treated by the U. S. Navy were civilians.

(2) Decompression sickness occurred following dives in which adequate decompression was used, or for which no decompression was specified in the U. S. Navy Decompression Tables.

(3) Tenders during treatment tables have occasionally developed decompression sickness.

(4) Decompression sickness is a disease of protean manifestations affecting several organ-systems. A comprehensive analysis of the clinical picture and treatment is included in the discussion section.

(5) The U. S. Navy Treatment Tables for decompression sickness are adequate.

(6) Chi square and correlational analyses of some of the data revealed the following:

(6.1) Prompt recompression treatment was usually associated with a better outcome ($X^2 = 19.0$ $p < .01$).

(6.2) In general, cases with a shorter time of onset of symptoms responded to treatment less satisfactorily than those with a longer time of onset ($X^2 = 8.76$ $p < .05$).

(6.3) Prompt recompression was related to the depth of relief ($C = .25$). Generally, the sooner recompression was started, the shallower the depth of relief.

(6.4) Cases with a shorter time before onset of symptoms generally obtained relief at a more shallow depth. The relationship, however, was very weak ($C = .15$).

(6.5) A weak relationship ($C = .15$) between depth of dive and depth of relief was found. Usually, the shallower the depth of the dive, the shallower the depth of relief.

Recommendations:

(1) The reasons for tenders acquiring decompression sickness during or after a treatment table should be investigated.

(2) A diver should not leave an area where a recompression chamber is available until 24 hours after completion of the dive.

(3) All cases of decompression sickness should be given a recompression trial no matter what the elapsed time since the onset.

(4) An investigation of a modification in the shallower depths (less than 30 feet) of the U. S. Navy Treatment Tables 3 and 4 is recommended. The possibility of shortening the 6 hour stops at 60 feet, 50 feet, and 50 feet of Treatment Table IV should be investigated.

APPENDIX B

DOLL--EDU RESEARCH REPORT 4-64

SUMMARY

Problem:

To obtain an estimate to the incidence of decompression sickness among U. S. Navy operational divers and to make a comparison between the relative efficiency of the old air decompression tables and the revised air decompression tables.

Procedure:

Incidence was obtained for three years (1958, 1960, 1961) using two sources of data: decompression sickness reports on file at the Experimental Diving Unit, and Diving Log Books, NAVSHIPS 1000 (Rev 11-57). Only dives made in the open sea requiring decompression were considered. Computed incidences were considered to be slightly inflated because a strong possibility existed that all the Diving Log Books were not made available to the author, and some cases of decompression sickness occurred from dives not requiring decompression.

Findings:

(1) For the three years a total of 7625 dives were made of which 62 resulted in decompression sickness for an incidence of 0.81 percent.

(2) The incidence using the old tables (1958) was 1.10 percent while the incidence for the revised tables (1960, 1961) was 0.69 percent.

(3) Relatively few dives of less than 100 feet were of sufficient duration to require decompression. However, a slightly higher incidence was found for dives of this category using the revised tables. Further investigation revealed that a disproportionate number of bends cases in this category (i.e. less than 100 feet) received insufficient decompression due to the administration of the wrong decompression tables. This, plus the unreliability of such small numbers, could easily account for what is seemingly a paradox.

(4) As a by-product of this study it was noted that for the 3 years of 1958, 1960, 1961 there were 721 dives performed requiring decompression on the U. S. Navy standard helium decompression tables resulting in 6 cases of reported decompression sickness for an incidence of 0.83 percent.

CONCLUSIONS AND RECOMMENDATIONS:

(1) Since the incidence of 0.69 percent for the revised tables must be considered to be somewhat inflated it would seem safe to conclude that the incidence of decompression sickness in U. S. Navy operational diving using present procedures is substantially less than 1.00 percent. The computed incidence of 1.10 percent for the old tables does not allow for such a conclusion. However, if the "true" incidence for the old tables was not less than 1.00 percent it was extremely close.

(2) Without knowing the extent of inflation for each of the computed incidences it is difficult to make a definitive comparison between the old air decompression tables and the revised air decompression tables. However, the obtainable estimate indicate a superiority of performance favoring the revised tables.

(3) It is recommended that a study of this nature be done on a periodic basis under more controlled conditions. Pertinent data for each case of decompression sickness and for each decompression dive should be put on ADP Cards allowing for continuous comprehensive examination of the problem of decompression sickness incidence.

APPENDIX C

GOODMAN----RESEARCH REPORT 5-65

SUMMARY

PROBLEM

During the two-year period 1963-1964, the Experimental Diving Unit received reports of 133 cases of decompression sickness in which U. S. Navy recompression treatment tables were applied. In 32 instances the initial recompression trial terminated in a clinically unsatisfactory manner: the patient did not obtain full relief of symptoms, or there was a reappearance of symptoms. Treatment tables 3 and 4 accounted for 62 of the initial therapeutic exposures and all but three of the failures, a 46.8% incidence of failure of the first recompression trial. There were no instances of clinical failure with tables 3 and 4, however, when antecedent exposures of Navy divers were conducted in accordance with procedures promulgated in the U. S. Navy Diving Manual.

FINDINGS

(1) Current U. S. Navy recompression procedures are, generally reliable therapeutic schedules for divers who have reported "pain-only" bends subsequent to exposures conducted in accordance with procedures promulgated by the U. S. Navy Diving Manual.

(2) Current U. S. Navy recompression procedures are, generally, inadequate in the management of severe decompression sickness following grossly inadequate decompressions from compressed-air dives.

(3) The recompression treatment procedures herein reported have afforded complete, firm relief to divers stricken with severe decompression sickness. Efficacy has also been demonstrated in fourteen cases which followed "saturation" dives, and in three cases of altitude dysbarism.

(4) Fifty-six percent of 79 reported cases fulfilled the standard criteria for manditory application of USN treatment tables 3 or 4. The incidence of unsatisfactory first-recompression results was 3.6% for the group managed within the limits of a "minimally-adequate" routine. Overall, there was an 8.9% failure incidence, and, for the adequately-managed cases, 2.0% failure of the initial recompression trials.

RECOMMENDATIONS

(1) Steps should be now initiated, and approval sought, for promulgation of these treatment procedures in the next edition of the Diving Manual.

(2) The current USN treatment tables should be retained, with the oxygen recompression procedures alternatively available, particularly for use with severely-stricken divers who have had grossly inadequate decompression.

APPENDIX D

DOLL & BERGHAGE----EDU RESEARCH REPORT 7-65

SUMMARY

PROBLEM

The objective of this study was to compute the interrelationships of several parameters of decompression sickness.

PROCEDURE

Information from reports on file at the U. S. Navy Experimental Diving Unit of 348 cases of decompression sickness among U. S. Navy divers for the years 1956-1962 was coded and punched on automatic data processing (ADP) cards. Chi-squares, contingency coefficients, and product-moment correlation matrices were computed.

FINDINGS

1. The type of dive resulting in decompression sickness is related to the three variables, "age", "type of work", and "delay between onset of symptoms and treatment".

2. The type of dive and the remaining seven parameters appear to be independent of each other.

3. The age of divers experiencing decompression sickness was found to correlate with the breathing medium (i.e. HeO2 or Air). Older divers experienced a significantly higher frequency of "bends" while breathing air.

4. There is a slight relationship between "time of onset of symptoms" and "breathing medium". Decompression sickness following HeO2 dives seems to manifest symptoms more quickly than after air dives.

5. The intercorrelation matrix of parameters for decompression sickness following single air dives revealed the following:

a. The deeper the dive is, the less the "bottom time" and the "severity of work". This is an expected relationship.

b. There is a negative correlation between the depth of the dive and the time it takes for symptoms to appear, and the delay between symptoms and treatment.

c. The longer the "bottom time", the heavier the build of the diver experiencing decompression sickness.

d. There is a negative relationship between the age of the "bent" diver and the severity of his work.

e. The longer it took for the symptoms to appear the longer was the delay between the symptoms and treatment.

6. The intercorrelation matrix of parameters for decompression sickness following HeO2 dives revealed the following:

a. The deeper dives had shorter bottom time.

b. Deeper dives required greater recompression to obtain full relief of symptoms.

c. The longer it takes for the symptoms to appear after a dive the greater the compression needed to obtain full relief.

7. The intercorrelation matrix of parameters for decompression sickness following repetitive dives revealed the following:

a. The deeper the dive the more rapid is the symptom manifestation and the less severe is the work.

b. A negative relationship was found between age and the time of onset of symptoms.

c. The longer the "delay between onset of symptom and treatment" the greater the depth of recompression required in order for full relief to be obtained.

APPENDIX E

BERGHAGE---EDU RESEARCH REPORT 1-66

SUMMARY

PROBLEM:

For future research in the area of diving accidents, it will be desirable to have a general statistical description of diving accidents within the United States Navy.

PROCEDURE:

All available diving accident reports, NAVMED 816, for the last ten years (1956-1965) were reviewed to obtain frequency distributions on various factors. The resultant distributions were divided into two five year time periods and evaluated for significant changes with the Chi-square statistic. Using the most descriptive time period, (either the full ten years or the last five years), statistics for a typical year were derived. These statistics are presented in graph form as the mean plus or minus one standard deviation.

FINDINGS:

(1) The average number of U. S. Navy diving accident reports received by the U. S. Navy Experimental Diving Unit per year is 77.9.

(2) Assuming that it takes four men to treat a diver with recompression, it is estimated that 4,600 (plus or minus 20 percent) man hours are so spent each year. An additional 3,800 (plus or minus 20 percent) man hours are required annually for treatment of civilians, foreign nationals, and other U. S. military personnel.

(3) The following diving accident variables have a significant difference ($p < .01$) between time periods, thus indicating a change in diving emphasis, equipment used, and/or reporting procedures over the last ten years.

Variable	Direction of change in the number of cases reported
Type of Accident:	
Decompression Sickness	decrease
Syncope	increase
Non pressure accidents	increase
Organ System Involved:	
Musculoskeletal pain	decrease
Type of Treatment	
Table 2	decrease
Treatment By	
Corpsman	increase

Variable	Direction of change in the number of cases reporte
Purpose of Dive	
Selection Dives	decrease
Experimental Dives	decrease
Requalification Dives	increase
Diver Qualification	
Deep Sea Divers	decrease
Underwater Swimmers	increase
Sport Divers	increase
Type of Equipment	
Submarine Escape	increase
Light Weight	decrease
Deep Sea HeO2	increase
SCUBA, Open	increase
SCUBA, Closed	increase
Chamber	decrease
Breathing Medium	
Air	decrease
Oxygen	decrease
Other Mixtures	increase
Decompression Schedules Used	
No Decompression Required	increase
Experimental	decrease

CONCLUSIONS:

(1) Because no accurate information is available on the actual number of dives made in the Navy it is impossible to determine if the number of accidents now incurred is excessive. Steps should be taken to determine the number of dives made by U. S. Navy divers. Without this information no true assessment of diving procedures or equipment can be made.

(2) A great reduction in the man hours required for pressure treatment can be obtained if the new minimal-recompression, oxygen breathing treatment tables, under development at the U. S. Navy Experimental Diving Unit, are adopted.

RR 1-66

APPENDIX F

KELLY, BERGHAGE, AND SUMMIT--EDU RESEARCH REPORT 10-68

SUMMARY

Problem:

To evaluate the diving accidents occurring during 1967 and compare the data with similar data available from previous report periods. To present case reports on some of the more informative diving accident occurring during 1967.

Procedure:

An analysis was conducted of all diving accidents occurring during 1967. The most common accident, decompression sickness among military personnel, was separated for detailed statistical analysis. Frequency distributions were constructed for variables within each section. The distribution of the characteristics of the 1967 accidents was compared with the same characteristics of accidents occurring in the years 1961-1966. A chi-square test was used to detect significant changes in the 1967 period versus the earlier periods.

Findings:

(1) The study confirmed the findings of previous reports that the results of treatment of decompression sickness is related to the amount of omitted decompression, time of onset of symptoms, and the delay in treatment.

(2) The study supports the conclusion by Dr. Goodman that the minimum oxygen treatment schedules are extremely useful in the treatment of serious decompression sickness after a long time delay in treatment.

(3) When comparing the accidents of 1967 with those of previous years, a significant change was noted in the following:

a. Qualification of the military diver having decompression sickness.

b. Number of divers reporting a previous incident(s) of decompression sickness.

c. Purpose of the dive.

d. Site of the dive, chamber, wetpot, open sea, etc.

e. Type of equipment used on dives resulting in decompression sickness.

f. Purpose of the dive.

g. Breathing medium used on dives resulting in decompression sickness.

h. Depth of the dive producing decompression sickness.

i. Bottom time of the dive producing decompression sickness.

j. Symptoms manifested and the organ systems involved.

k. Depth of relief of symptoms (but not the time of relief of symptoms). This is probably related to the introduction of the new minimum oxygen treatment schedules for fleet use.

l. Type of treatment schedule utilized in treating decompression sickness.

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