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ASSESSING THE SHORT- AND LONG-TERM HEALTH EFFECTS OF  
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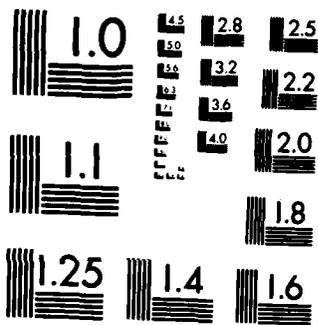
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# ASSESSING THE SHORT- AND LONG-TERM HEALTH EFFECTS OF DECOMPRESSION SICKNESS AMONG U.S. NAVY DIVERS

A. HOIBERG

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ASSESSING THE SHORT- AND LONG-TERM HEALTH EFFECTS  
OF DECOMPRESSION SICKNESS AMONG U.S. NAVY DIVERS

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## SUMMARY

### Problem

The most frequently occurring job-related mishap among U.S. Navy divers is decompression sickness (DCS). Researchers have reported that the symptoms of Type I DCS tend to disappear within days or weeks of initial treatment; however, little is known of the subsequent health consequences of DCS. Research is needed to identify the health risks of DCS that divers face as they pursue this occupation in the Navy.

### Objectives

The purpose of this longitudinal study was to identify the short- and long-term health effects among U.S. Navy divers who suffered DCS during a time period of more than a decade ( $n = 362$ ) and to compare their rates of hospitalizations and medical boards with a matched sample of divers who had no recorded diving accidents ( $n = 1,086$ ).

### Approach

Frequency and percentage distributions were computed to identify DCS divers who had been separated from service and/or who had been hospitalized or reviewed by a medical or physical evaluation board subsequent to the DCS incident. Each diagnosis and the numbers of days, weeks, and years after the mishap date were listed in a tabular chronology in order to examine illness incidence by time interval. After compiling these frequencies of diagnoses into 11 categories and calculating person years at risk for DCS divers, annual rates per 10,000 strength were computed. Comparisons with the control sample were conducted after calculating the control divers' hospitalization rates per 10,000 strength. Ninety-five percent confidence limits, based on the Poisson distribution (for rarely occurring events), were computed to determine whether or not rate differences between samples were significant for any diagnostic category. Comparisons of mean values for age and a weight/height index were conducted between the DCS sample and all other divers. The  $t$ -test technique was performed to ascertain the level of statistical significance between samples for these two variables.

### Results

Of the 332 divers included in the analyses, results identified 251 individuals (75.6%) whose records contained no diving-related medical events after the DCS accident. No deaths and only three physical disabilities were specifically attributed to DCS or diving. Other serious health consequences were observed for two divers hospitalized with a spinal cord lesion and three with ear injuries. An examination of the remaining hospitalizations for DCS divers revealed significantly higher rates than controls for four of the 12 comparisons. The total hospitalization rate for DCS divers was three times higher than that for the control group. DCS divers had higher rates than controls for all 11 diagnostic clusters, three of which were significantly higher (symptoms and headache, diseases of the arteries and veins, and diseases of the pancreas, intestines, and gallbladder). Other results showed that DCS divers were significantly heavier, but not older, than all other divers.

### Conclusions

This longitudinal study identified all illnesses requiring inpatient medical care in a sample of DCS divers as well as those disorders that differentiated this sample from controls. Caution should be exercised in interpreting the significant results because the number of DCS divers hospitalized for each diagnosis or category was very low and there were no data available that specifically implicated DCS as the cause of a subsequent illness. Also, it was impossible to pinpoint a specific time period of increased vulnerability for a subsequent DCS-related health problem.

### Recommendations

The significant findings of this study should be viewed as forming the basis on which to conduct future research on DCS incidence. To determine whether or not DCS divers are at increased risk for several diagnostic categories, subsequent research should include medical information from inpatient and outpatient records as well as from questionnaires designed to obtain divers' responses pertaining to their mental and physical condition.

**Assessing the Short- and Long-term Health Effects  
of Decompression Sickness among U.S. Navy Divers**

The risk of experiencing a diving mishap among U.S. Navy divers has been determined to be quite low; of more than 700,000 recorded submergences from 1968 through May 1981, the proportion of mishaps reported was 0.17% (1). The most frequently occurring mishap was decompression sickness (DCS), which accounted for 41.1% ( $\underline{f} = 426$ ) of the total number of accidents. Of the dives requiring some form of decompression, 0.70% resulted in a DCS incident. Using data analyzed in Rivera's comprehensive study of DCS (2), Strauss (3) reported a comparable incidence rate of 0.69% among 722 U.S. Navy divers for the 1946-61 time period.

The symptomatology of DCS, which includes Type I and Type II manifestations, has been described in numerous texts and journal articles (4-8). Kidd and Elliott (5) indicated that differentiating between the two types can be difficult because Type I symptoms may mask or precede the more serious Type II manifestations. The Type I category consists of DCS cases in which 1) pain is the only symptom, 2) joint pain is experienced in conjunction with cutaneous or lymphatic implications, and 3) incidents are manifested by cutaneous or lymphatic involvement without pain. Type II cases are of a more serious nature with central nervous system, peripheral neuropathy, or respiratory involvement. Of the 22 symptoms listed on the U.S. Navy diving accident log the highest percentages of the most "significant sign" associated with a DCS mishap were localized pain (74.9%), numbness (9.4%), muscular weakness (3.1%), dizziness (3.1%), and rash (2.8%).

If treated immediately, the symptoms of Type I DCS would be expected to disappear without residual (3). In their study of three DCS cases occurring after deep excursion dives, Greene and Lambertsen (9) reported that complete relief with no aftereffects was accomplished as a result of prompt treatment. Other researchers (6) have shown that approximately 24% of the DCS cases among scuba divers "have some neurological consequence involving the spinal cord and the potential to render a victim permanently paraplegic." In Rivera's study of 935 DCS cases (2), a total of 51 divers (5.4%) suffered residual effects and three divers died (0.3%) because of DCS. Although follow-up data were not available on all divers, Rivera reviewed almost all cases and reported a remarkably high recovery rate after several days or weeks for those divers who received immediate physical therapy. Similarly, Berghage (10) determined that the subsequent recompression treatment of 27 saturation decompression sickness cases resulted in full relief after two hours for 35% of the divers while the rest of the sample (65%) completed the therapy and decompression with residual pain that diminished over a period of weeks.

While those investigators determined that the aftereffects of DCS tended to disappear within weeks of initial treatment, little is known of the subsequent health consequences of DCS. Manifestations may not be apparent until years later when dysbaric osteonecrosis or malignant fibrous histiocytoma are discovered (6,11). A significant relationship between these rarely occurring disorders and DCS has been described by several researchers (11-13). The purpose of this longitudinal study was to identify the short- and long-term health effects among U.S. Navy divers who suffered DCS during a time period of more than a decade and to compare their rates of morbidity

(hospitalizations and medical board appearances) with a matched sample of divers who had no recorded diving accidents. The influence of age and weight on the incidence of DCS also was examined.

#### METHOD

Subjects for this study included 338 U.S. Navy enlistees and 24 diving officers who were identified as having experienced DCS during the time period from January 1968 through May 1981; the total Navy diving population consisted of 11,664 enlistees and 2,027 officers. The mean age at the time of the DCS mishap was 27.9 with a range from 17 to 44. Among enlistees, the median pay grade was E-6, and, among officers, the median rank was lieutenant. Of the 130 women divers on the diving log file, two suffered a DCS incident.

To determine whether members of the DCS sample had elevated hospitalization rates subsequent to the targeted incident, their rates were compared with those for a sample of divers who had no recorded diving accident. Selection of this sample was accomplished by matching the birth years of individuals in the DCS sample with those of all other divers. The reason birth year was used as a controlling variable was that in previous research (14) increasing age was shown to be significantly related to higher rates for several musculoskeletal and circulatory disorders as well as alcohol/drug abuse, diabetes mellitus, and diseases of the respiratory tract. Although it was deemed desirable during the planning phase of this study to control on such variables as number, depth, and type of dives performed, these diving log data were only available in summarized form and, therefore, could not be appropriately used in selecting the control sample. The control sample consisted of 1,014 enlistees and 72 officers (three divers were identified for each person in the DCS sample).

#### Procedure

Information for this study was obtained from three data bases maintained at the Naval Health Research Center in San Diego (Medical Inpatient, Officer Career History, and Enlisted Service History files) and the computerized file of Diving Log-Accident/Injury Reports (OPNAV 9940/1) which was provided by the Naval Safety Center in Norfolk, Virginia. Data extracted from the diving file included birth year, height, and weight as well as age, pay grade, and date at the time of each DCS accident. Data selected from the Medical Inpatient file consisted of date and diagnoses for each hospitalization, medical board action, and physical evaluation board appearance as well as the underlying cause and date of death. The diagnostic nomenclature used was the Eighth Revision of the International Classification of Diseases Adapted for Use in the United States (ICDA-8). Information on the dates of entry and separation from naval service was obtained from the Officer Career History or Enlisted Service History files.

For the first phase of the study, frequency and percentage distributions were performed to identify divers in the DCS sample who were separated from service and/or who had been hospitalized or reviewed by a medical board subsequent to the DCS incident. For those who had a recorded medical event, each of the diagnoses and the numbers of days, months, and years after the mishap date were listed in a tabular chronology. These entries represented the diagnoses for all physical disabilities, medical boards, and hospitalizations that occurred in conjunction with the

mishap and during each subsequent year after the DCS incident. Thirty divers in the DCS sample were eliminated from these compilations because medical inpatient data were unavailable during their follow-up period.

For the second phase, the frequencies of hospitalizations and medical board actions for DCS divers were compiled into diagnostic clusters (e.g., disorders of the back, symptoms and headache, and disorders of the joint, knee, and connective tissue). The number of person years at risk for these divers was determined by summing the number of individuals on active duty for each year subsequent to the targeted incident. Using these person years, annual rates per 10,000 strength were computed for the 11 post-DCS diagnostic categories. Comparisons with the control sample were conducted after calculating the control divers' hospitalization rates per 10,000 strength for the 11 categories. Person years at risk for the control sample were obtained by summing the number of these divers on active duty year by year throughout the 1968 to 1979 time period. Ninety-five percent confidence limits, based on the Poisson distribution (for rarely occurring events), were calculated to establish whether or not rate differences between samples were significant for any of the diagnostic categories.

Because increasing age and obesity have been implicated as risk factors of DCS (2,6,15-16), comparisons of mean values for age and a weight/height index (kilogram/meter<sup>2</sup>) were conducted between the DCS sample and all other members of the diving community ( $n = 13,329$ ). The  $t$ -test technique was performed to ascertain the level of statistical significance between samples for these two variables.

#### RESULTS

Of the 332 DCS divers included in the analyses, 146 divers (44.0%) had no records of hospitalizations, board actions, or medical separations either before or after the targeted incident; 70 divers (21.1%) were noted for only having a hospitalization or board appearance prior to the diving mishap; and 35 divers (10.5%) were determined to have hospital admissions and board actions for reasons unrelated to diving, such as motorcycle and automobile accidental injuries, assault injuries, cellulitis, and hemorrhoids. These three subcategories accounted for 75.6% of the DCS sample.

The remaining cases (24.4%) included divers who were separated from active duty for medical reasons, divers who were hospitalized immediately after the mishap, and individuals who were hospitalized subsequent to the mishap. Data for each of these groups were examined to determine whether or not the medically related incident might have occurred as a result of the DCS incident.

#### Death and Disability

Of the DCS sample, one person died and 14 were retired or separated with a physical disability. There was no information reported on the cause of death or for two of the cases of permanent disability. Only three physical disability retirements were specifically attributed to the DCS mishap or to diving; the primary diagnosis included DCS for two divers (one had a secondary diagnosis of spinal cord lesion) and vertebrogenic pain syndrome/lumbalgia for the third, as shown in Table 1. The other nine divers were diagnosed with various disorders such as osteoarthritis, arthritis, other deformities of the leg, and diabetes mellitus.

TABLE 1  
 PHYSICAL EVALUATION BOARDS BY DIAGNOSIS AND TIME PERIOD  
 SUBSEQUENT TO DECOMPRESSION SICKNESS (DCS)  
 FOR U.S. NAVY DIVERS, 1968-1979

Diagnosis (ICDA-8 Rubrics)	Time Period Since DCS
Decompression sickness	8 months
Information unavailable	13 months
Malignant neoplasm of testis	18 months
Decompression sickness	2 years
Osteoarthritis and allied conditions (spondylitis osteoarthritis)	2 years, 2 months
Information unavailable	2 years, 3 months
Other and unspecified infective and parasitic disease	2 years, 11 months
Dislocation of hip (automobile accident)	3 years, 6 months
Chronic ischemic heart disease (without mention of hypertensive disease)	5 years, 4 months
Other deformities of leg	5 years, 11 months
Vertebrogenic pain syndrome (on-duty diving)	7 years, 1 month
Diabetes mellitus (without mention of acidosis or coma)	8 years
Disease of the pancreas (chronic pancreatitis)	8 years, 11 months
Arthritis, unspecified	8 years, 11 months

Immediate Hospitalization

Thirty-eight divers (11.4%) were hospitalized immediately as a result of a DCS incident: 36 were diagnosed with DCS and two were admitted for air embolism. Eight of these divers had secondary or additional diagnoses which are listed in Table 2. The most prevalent secondary diseases were injuries and diseases of the ear (3 divers), spinal cord lesions (2), and pneumonia (2). In examining the subsequent medical events for these 38 divers, 30 had no hospitalization or medical separation, four were hospitalized, two were retired on permanent disability as a result of DCS, and two were hospitalized and then discharged with a physical disability (one for arthritis and the other for deformities of the leg).

TABLE 2  
 FREQUENCY DISTRIBUTION OF SECONDARY OR ADDITIONAL DIAGNOSES  
 WITH DECOMPRESSION SICKNESS (DCS) FOR U.S. NAVY DIVERS  
 HOSPITALIZED IMMEDIATELY FOR DCS, 1968-1979

<u>Diagnosis (ICDA-8 Rubrics)</u>	<u>DCS Divers No.</u>
Spinal cord lesion without evidence of spinal bone injury (unspecified with open wound)	1
Spinal cord lesion without evidence of spinal bone injury (unspecified, without mention of open wound)	1
Pneumonia, primary atypical (other specific organism or cause) and open wound of ear (without infection)	1
Pneumonia, primary atypical (other specific organism or cause) and foreign body in ear (without infection)	1
Emphysema	1
Other symptoms referable to nervous system and special senses (other disturbances of sensation)	1
Other diseases of ear and mastoid process and other diseases of muscle, tendon, and fascia (muscular atrophy, idiopathic)	1
Alcoholism (other and unspecified)	1

Subsequent Hospitalizations during the First Year

During the first year after the DCS incident, one diver from the physical disability sample, three divers who had been immediately hospitalized for DCS, and eight other divers were hospitalized for various diagnoses, as can be seen in Table 3. The number of days or months since the initial DCS incident also is indicated. Of these cases, seven divers were diagnosed with conditions that have been identified in the literature as related to diving and/or DCS, although several of these conditions typically occur as immediate manifestations of DCS. These seven diagnoses included a diving-related spinal cord lesion which occurred 12 days after the DCS incident, symptoms referable to the abdomen and lower gastrointestinal tract (abdominal pain), vertigo, headache, other anomaly of the lumbosacral joint and vertebrogenic pain syndrome, and arthritis. The other diagnoses included such disorders as essential benign hypertension and transient situational disturbances.

Subsequent Hospitalizations after One Year

During a time period from 14 months to almost 11 years, the number of divers hospitalized consisted of seven divers from the physical disability sample, one diver who had had an immediate hospitalization, and 24 other divers. As shown in Table 4, the highest number of hospitalizations was observed for joint, knee, and back disorders; arthritic conditions; and respiratory disorders. One individual, who had six automobile accident-related hospitalizations and medical boards, was not included in the tabular presentation.

TABLE 3  
 DIAGNOSES FOR SUBSEQUENT HOSPITALIZATIONS (< 1 YEAR) AMONG  
 U.S. NAVY DIVERS WITH DECOMPRESSION SICKNESS (DCS),  
 1968-1979

Diver	Diagnosis (ICDA-8 Rubrics)	Time Period Since DCS
1	Symptoms referable to the abdomen and lower gastro-intestinal tract (abdominal pain)*	5 days
2	Spinal cord lesion without evidence of spinal bone injury (cervical, without mention of open wound) and spinal cord lesion (dorsal and lumbar, without mention of open wound) (diving related)	12 days
3	Chronic enteritis and ulcerative colitis (first admission) Arthritis, unspecified (second admission)*	46 days 70 days
4	Anomalies of lumbosacral joint and vertebrogenic pain syndrome	54 days
5	Certain symptoms referable to nervous system and special senses (vertigo) and special symptoms (cephalalgia)*	75 days
6	Transient situational disturbances	100 days
7	Phlebitis and thrombophlebitis	7 months
8	Symptoms referable to limbs and joints (pain in limb)**	8 months
9	Other diseases of respiratory system (pulmonary collapse) and chronic sinusitis (first admission) Chronic sinusitis (second admission) Sprains and strains of knee and leg (unknown cause) (third admission)	9 months 16 months 45 months
10	Headache, unspecified cause	10 months
11	Essential benign hypertension and symptoms referable to respiratory system (pain in chest) (first admission) Symptoms referable to respiratory system (pain in chest) and essential benign hypertension (second admission)	11 months 32 months
12	Essential benign hypertension and ulcer of duodenum (third admission)	11 months

\*Subsequent hospitalization(s) for divers hospitalized immediately for DCS.    \*\*Hospitalization(s) for DCS divers who subsequently were discharged with a physical disability.

Hospitalization Rates for DCS Divers and Controls

After excluding such disorders as spinal cord lesion and effects of air pressure, the specific diagnoses in Tables 3 and 4 were compiled into 11 clusters, and annual hospitalization rates per 10,000 strength were computed for these categories within both the DCS and control samples (see Table 5). In examining the 95% confidence limits between samples, four comparisons yielded significantly higher rates for the DCS sample than the control group: symptoms and headache; disorders of the arteries and veins; diseases of the pancreas, intestines, and gallbladder; and total hospitalizations. Three other clusters, which were concentrated in the musculoskeletal

TABLE 4  
 DIAGNOSES FOR SUBSEQUENT HOSPITALIZATIONS (> 1 YEAR) AMONG  
 U.S. NAVY DIVERS WITH DECOMPRESSION SICKNESS (DCS),  
 1968-1979

Diver	Diagnosis (ICDA-8 Rubrics)	Time Period Since DCS
1	Phlebitis and thrombophlebitis (other, unspecified sites)	1 year, 2 months
2	Effects of air pressure (other and unspecified effects of high altitude), other aneurysm, and essential benign hypertension	1 year, 3 months
3	Deflected nasal septum*	1 year, 4 months
4	Alcoholism (other and unspecified)	1 year, 4 months
5	Osteoarthritis and allied conditions and arthritis, unspecified	1 year, 6 months
6	Symptoms referable to limbs and joint (pain in joint)	1 year, 7 months
7	Other muscular rheumatism, fibrositis, and myalgia	1 year, 8 months
8	Sprains and strains of sacroiliac region and neurosis (depressive) (first admission)	1 year, 8 months
	Vertebrogenic pain syndrome (lumbalgia) (second admission)	6 years, 2 months
	Vertebrogenic pain syndrome (lumbalgia) (third admission)	6 years, 5 months
	Vertebrogenic pain syndrome (other and unspecified) (fourth admission)**	6 years, 11 months
9	Other diseases of joint/chondromalacia of knee (first admission)	1 year, 10 months
	Other deformities of leg, dislocation of knee, and osteoarthritis (second admission)**	3 years, 7 months
10	Symptoms referable to limbs and joints (pain in joint--arthralgia) and other unspecified infective-parasitic diseases (first admission)	2 years, 1 month
	Other and unspecified infective-parasitic diseases (second admission)**	2 years, 8 months
11	Other ill-defined and unknown causes of morbidity and mortality	2 years, 2 months
12	Internal derangement of joint (other knee derangement)	2 years, 4 months
13	Deflected nasal septum (first admission)	3 years, 2 months
	Deflected nasal septum (second admission)	4 years
14	Sprains and strains of other and unspecified parts of back and anomalies of lumbosacral joint (first admission)	3 years, 5 months
	Vertebrogenic pain syndrome (lumbalgia) and sprains and strains of other unspecified parts of back (second admission)	3 years, 11 months
	Displacement of intervertebral disc (lumbar and lumbosacral) and unspecified site (third admission)	4 years, 8 months
	Other anomalies of larynx, trachea, and bronchus (fourth admission)	6 years, 9 months
15	Transient situational disturbances (first admission)	3 years, 6 months
	Transient situational disturbances (second admission)	3 years, 8 months
16	Internal derangement of joint (other knee derangement)	3 years, 7 months
17	Diseases of the intestines and peritonium	3 years, 10 months
18	Neoplasm of unspecified nature of skin and musculoskeletal system (bone and cartilage) (first admission)	4 years, 1 month
	Neoplasm of unspecified nature of eye, brain, and other parts of nervous system (spinal cord) (second admission)	4 years, 3 months
	Other diseases of spinal cord (third admission)	4 years, 7 months
	Certain symptoms referable to nervous system and special senses (abnormal involuntary movement) (fourth admission)	4 years, 10 months

Diver	Diagnosis (ICDA-8 Rubrics)	Time Period Since DCS
	Other diseases of joint (fifth admission)	5 years, 1 month
19	Alcoholism (alcoholic addiction) (first admission)	4 years, 1 month
	Alcoholism (alcoholic addiction) (second admission)	4 years, 9 months
20	Symptoms referable to cardiovascular and lymphatic system (syncope or collapse) and injury, other and unspecified (trunk)	4 years, 8 months
21	Chronic ischemic heart disease, gangrene, and benign neoplasm of bone and cartilage**	5 years, 1 month
22	Alcoholism (alcoholic addiction)	5 years, 3 months
23	Diseases of the pancreas (acute pancreatitis) and symptoms referable to abdomen and lower gastrointestinal tract (abdominal pain) (first admission)	5 years, 5 months
	Dislocation of knee (second admission)	6 years
	Internal derangement of joint (other knee derangement) (third admission)	7 years, 9 months
	Other diseases of muscle, tendon, and fascia (residual foreign body in tissue or bone (fourth admission)	8 years
	Other diseases of joint (fifth admission)	10 years, 7 months
24	Alcoholism, improper use of drugs, and essential benign hypertension	5 years, 5 months
25	Vertebrogenic pain syndrome (lumbalgia)	5 years, 11 months
26	Osteoarthritis (spondylitis osteoarthritica) (first admission)	6 years, 2 months
	Osteoarthritis (spondylitis osteoarthritica) (second admission)	6 years, 5 months
	Osteoarthritis, other congenital anomaly of musculoskeletal system (abnormality of spine), personality disorder (other), and arthritis (unspecified) (third admission)**	7 years, 11 months
27	Arterial embolism and thrombosis (of mesenteric artery)	6 years, 10 months
28	Occlusion of precerebral arteries (without mention of hypertension) (first admission)	7 years, 10 months
	Arterial embolism and thrombosis (of other and unspecified arteries) (second admission)	7 years, 10 months
29	Diseases of the pancreas (chronic pancreatitis)**	8 years, 7 months
30	Other diseases of the gallbladder	8 years, 7 months
31	Sprains and strains of knee and leg (first admission)	8 years, 9 months
	Internal derangement of joint (other knee derangement) (second admission)	9 years
32	Essential benign hypertension**	Unknown

\*Subsequent hospitalization(s) for divers hospitalized immediately for DCS. \*\*Hospitalization(s) for DCS divers who subsequently were discharged with a physical disability.

system, accounted for almost one-half of all post-DCS admissions: disorders of the joint, knee, and connective tissue; disorders of the back; and arthritic conditions. Rates for these three categories as well as the remaining five clusters failed to significantly differentiate the DCS sample from the control group.

TABLE 5  
ANNUAL HOSPITALIZATION RATES BY DIAGNOSTIC CATEGORY FOR  
U.S. NAVY DIVERS WITH DECOMPRESSION SICKNESS (DCS) AND CONTROLS,  
1968-1979

Diagnostic Category (ICDA-8 Codes)	DCS Divers		Controls	
	No.	Rate per 10,000	No.	Rate per 10,000
Disorders of joint, knee, and connective tissue (724.5, 729.7, 729.9, 733.6, 738.5, 836.0, 836.9, 844.0)	18	120.2	47	59.7
Disorders of back (349.9, 725.1, 725.9, 728.7, 728.8, 728.9, 756.2, 846.0, 847.8)	13	86.8	42	53.3
Symptoms and headache (306.8, 780.3, 780.5, 782.5, 783.7, 785.5, 787.1, 787.3, 791.0)	12	80.2*	10	12.7
Osteoarthritis, arthritis, and rheumatism (713.0, 713.1, 715.0, 717.9)	10	66.8	15	19.0
Diseases of respiratory system (504.0, 519.0, 748.3)	7	46.8	13	16.5
Alcoholism and drug abuse (303.2, 303.9, 793L)	6	40.1	22	27.9
Diseases of circulatory system (401.0, 412.0)	6	40.1	6	7.6
Diseases of pancreas, intestines, and gallbladder (532.9, 563.0, 569.9, 576.9, 577.0, 577.1)	6	40.1*	2	-
Disorders of the arteries and veins (432.9, 442.0, 444.2, 444.9, 451.0, 451.9)	6	40.1*	1	-
Transient situational disturbances (307.0)	3	20.0	5	6.4
Benign and unspecified neoplasms (213.0, 232.0, 238.4)	3	20.0	1	-
Total hospitalization rate	90	601.2*	164	208.3
Person years at risk	1,497		7,873	

\*Rate differs significantly ( $p < .05$ ) between DCS sample and controls as determined by nonoverlapping confidence intervals. Rates are based on admissions recorded subsequent to the DCS incident for DCS divers and during the 1968-1979 time frame for controls. Rates are not presented for diagnoses with frequencies less than 3.

#### Influence of Age and Weight on DCS Incidence

In comparisons of mean ages, the DCS sample had a somewhat higher, albeit nonsignificant ( $t = 1.88$ ), mean age than all other members of the diving community (27.9 vs. 27.3). DCS divers, however, were significantly heavier than other divers, with a mean weight/height ratio of 25.0 vs. 24.3 ( $t = 5.3$ ;  $p < .001$ ).

#### DISCUSSION

Of the 332 divers included in the analyses, results of this study identified 251 individuals (75.6%) whose records contained no diving-related medical events after the DCS accident. No deaths and only three physical disabilities were specifically attributed to DCS or diving. Other serious health consequences were observed for two divers hospitalized with a spinal cord lesion and three with ear injuries; none of these five divers had a subsequent hospitalization or medical separation. Thirty other divers also were hospitalized immediately as a result of DCS. Thus, a

total of 38 divers or 11.4% of the sample accounted for the most serious and immediate medical consequences of DCS. For these and the rest of the sample (13.0%), an examination of their post-accident hospitalization records revealed four significantly higher rates than controls which were evaluated as possible aftereffects of DCS.

The total hospitalization rate for DCS divers was three times higher than that for the control group. In comparisons of rates by diagnostic category, DCS divers had higher rates than controls for all 11 clusters, three of which were significantly higher (symptoms and headache, diseases of the arteries and veins, and diseases of the pancreas, intestines, and gallbladder). In explaining these significant differences, it is important to emphasize that although the two groups were matched on birth year, they differed with regard to their diving accident histories. DCS divers had at least one DCS incident, as contrasted with no accidents of any kind for controls. This difference alone suggested that DCS divers might have performed more deeper dives than controls--and ones of greater risk for an injury or diving-related disease. After excluding such conditions as alcoholism and transient situational disturbances, almost all of the diagnoses observed in the DCS sample were indeed those identified in the literature as diving related. For example, the cluster of symptoms and headache was comprised of such conditions as abdominal pain, vertigo, pain in the limb, pain in the joint, chest pain, and headache, all of which have been identified as Type I DCS symptoms (4). Further, higher rates for the category of disorders of the arteries and veins seemed to reflect an increased risk for conditions associated with bubble nucleation and growth.

Before concluding that these conditions were causally related to DCS, two major issues need to be addressed. First, the number of divers hospitalized for each diagnosis or category was very low which would temper any conclusion attributing incidence of these disorders to the DCS incident. That is, no specific diagnosis showed an elevated rate of occurrence. For example, the number of hospital admissions and medical boards for any specific diagnosis did not exceed five, which was observed only for arthritis and essential benign hypertension. Caution also should be exercised in interpreting these results because there were no data available that specifically implicated DCS as the cause of a subsequent illness. These results also seemed to reflect the "healthy worker" effect. To serve in the Navy, an applicant must meet specified physical and mental standards. To serve as a Navy diver, even more stringent qualifications must be met. Thus, one would expect to observe relatively low hospitalization rates in the Navy diver population which generally was shown to be the case in comparisons of rates between Navy enlisted divers and a matched sample of enlistees (17).

Second, the factor of time should be examined in discussing these significant results. For the cluster of symptoms and headache, only one hospitalization (for abdominal pain) occurred sufficiently close in time to the accident to be considered a consequence of DCS. The other admissions in this category were recorded during a time period from 2.5 to 25 months subsequent to the DCS accident. Incidence of the disorders subsumed under the other two categories was observed throughout the 11-year follow-up period with no specific year interval evidenced as a time of increased risk. On the basis of these considerations, it would be impossible to pinpoint a

specific illness or time period of increased vulnerability for a subsequent DCS-related health problem.

Although there was no clear-cut evidence in support of a causal relationship, the higher rates among DCS divers may be a manifestation of an increased susceptibility for these disorders as a result of the DCS incident. Furthermore, the higher incidence of these disorders may have occurred as a consequence not only of the DCS incident but also as a result of the accumulating effects of hyperbaric exposures. Therefore, a diver who suffers DCS and continues to work as a diver might expect to be at increased risk for these conditions.

Other results of this study showed that DCS divers were not on the average older than all other divers which suggested that their mean age could not be considered a risk factor of DCS. Similar to findings reported elsewhere (15, 16), divers in the DCS sample were significantly heavier than all other divers.

In conclusion, this longitudinal study identified all illnesses requiring hospitalization in a sample of DCS divers as well as those disorders that differentiated this sample from controls. Because of the aforementioned considerations, the significant findings should be viewed as forming the basis on which to conduct future research on DCS incidence. In addition to hospitalization data, records of outpatient care should be examined to determine whether or not divers received treatment for these conditions in an outpatient facility. Medical information also should be collected from questionnaires designed to obtain divers' responses pertaining to their mental and physical condition. Results of the present and future research efforts should identify with greater confidence the health risks that divers face as they pursue this occupation in the U.S. Navy.

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DCS divers had significantly higher rates than controls for total hospitalizations, symptoms and headache, diseases of the arteries and veins, and diseases of the pancreas, intestines, and gallbladder. No specific disease or time interval was identified as attributable to the DCS incident. Subsequent research should include medical information from outpatients' records and divers' questionnaires to determine with greater confidence the health risks that divers face as they pursue this Navy occupation.

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