

Decompression sickness in women divers

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Zwingelberg KM, Knight MA, Biles JB. Decompression sickness in women divers. *Undersea Biomed Res* 1987; 14(4):311-317.—The comparative incidence of DCS in women has been debated for years. Diving log data from the Naval Diving and Salvage Training Center (NDSTC), Panama City, FL, demonstrate that there is no increased risk of DCS among Navy female divers compared to their male counterparts. Twenty-eight female students were compared to their 487 male classmates on 878 air and helium-oxygen dives between 4.64 and 10.10 ATA (120 to 300 fsw). None of the women experienced DCS while 8 men developed DCS symptoms. The total duration of the dives ranged from 8 min to 2 h and 6 min; bottom times were less than 20 min. Theoretical inert gas supersaturation on these profiles are commensurate with those experienced on 40- to 60-min sport scuba dives.

decompression sickness
bends
body fat

women and diving
decompression schedules
helium-oxygen

altitude DCS

Decompression sickness (DCS) in women has been the topic of various papers and symposiums over the past 15 yr. Bassett (1) has reported that women are more susceptible to altitude DCS than men. Bassett's study examined altitude chamber exposures in medical aviation candidates and found a fourfold greater incidence of DCS in women as compared with similar altitude exposures in men.

Bangasser (2) performed a retrospective questionnaire study of 649 female divers in 1973. Of 44,154 estimated dives in a subgroup of women instructors, Bangasser found 10 confirmed or suspected cases of DCS (0.023%). In 43,126 estimated male instructor dives, 3 suspected DCS cases (0.007%) were identified. This would seem to yield a 3.3-fold greater incidence of DCS among women divers.

The Bangasser study suffered from several weaknesses. It was a retrospective evaluation, all conditions were not known, cases with insufficient data may not have been fully scrutinized, no controlled criteria existed to determine if DCS actually occurred, and the diagnostic evaluations were based solely on the respondents. Moreover, it is unlikely that divers incapacitated by accidents or suffering fatalities were accounted for in the study.

Bassett's study, though better controlled, was an altitude DCS study and may or may not apply to diving DCS. Diving and altitude exposures result in considerably different theoretical inert gas supersaturation profiles. To date, a definitive, detailed study of female DCS in diving has not been completed. The purpose of this study was to determine if there is an increased incidence of DCS in female divers, when compared to male divers.

The U.S. Navy has been training female divers for over 10 yr. In the last 6 yr most of this training has occurred at the Naval Diving and Salvage Training Center (NDSTC), Panama City, FL. During these years, approximately 6000 students have been trained at NDSTC; 29 of those students were females. With the increased emergence of females in military diving and the benefit of well-documented and controlled dives, it is now possible to examine the incidence of DCS in female divers.

METHODS

The study was a two-part analysis of dives performed by females at NDSTC as compared to the dives conducted by the male divers who began training in the same instructional group (i.e., class). First, the women were compared to their male classmates in a general review of DCS incidence on deep dives. "Deep" dives examined in the study were between 4.64 and 9.64 ATA (120 and 285 fsw on air and between 4.64 and 10.10 ATA (120 and 300 fsw) on He-O₂. The total duration of the dives ranged from 8 min to 2 h 6 min; bottom times were less than 20 min. Dives were conducted with strict adherence to the U.S. Navy Air and Helium-Oxygen Decompression Schedules (3, 4). No "surface decompression" deep dives were performed. All deep dives were performed in the NDSTC pressure vessel assemblies (PVA). A PVA is a chamber complex with both wet and dry compartments. It allows training dives to be conducted with the student divers in a highly controlled environment. PVA dives are generally performed with 2, but occasionally up to 11 divers in the wet compartment. All divers, therefore, undergo an identical compression-decompression profile during a dive.

A second female-to-male "buddy" matched analysis was done on deep dives involving females. This match compared the female divers directly with male "buddy divers" who were concurrently undergoing the identical PVA dive profile.

A binomial analysis was performed on both parts of the study, comparing NDSTC deep-dive DCS rates with Bassett's altitude DCS rates for females and males (5).

Twenty-nine women performed dives as members of 36 diving classes at NDSTC between November 1982 and June 1986. One woman began training but failed to reach the deep-diving phase; 571 men began training with these women, and 487 performed deep dives while classmates of the women. Women have been trained in all aspects of U.S. Navy diving from basic scuba to deep-sea He-O₂ diving. All women were under the age of 35 with both officer and enlisted ranks represented in each sex.

RESULTS

Based on training requirements, divers in the study completed an estimated 14,374 dives (Table 1). Of these dives, 878 (6.1%) were to depths greater than 4.64 ATA

TABLE 1
MINIMUM CURRICULUM REQUIREMENTS FOR FEMALE DIVERS AND THEIR MALE CLASSMATES

Class	Males			Females				
	No.	(%)*	Total Dives	Total Deep Dives**	No.	(%)*	Total Dives	Total Deep Dives**
SC	12	(2.6)	168	12	1	(3.6)	14	1
2C	219	(47.2)	7008	219	12	(42.9)	384	12
BDO	115	(24.8)	3565	115	12	(42.9)	372	12
SO	82	(17.7)	164	0	6	(21.4)	12	0
MU	31	(6.7)	0	0	6	(21.4)	0	0
1C†	74	(15.9)	1332	370	4	(14.3)	72	20
He-O ₂ †	3	(0.6)	48	15	1	(3.6)	16	5
DMT†	15	(3.2)	615	105	2	(7.2)	82	14
DMO†	27	(5.8)	486	135	2	(7.2)	36	10
HT	13	(2.8)	0	0	1	(3.6)	0	0
Totals:	591†		13,386	971	47†		988	74

SC = Basic SCUBA, 2C = Second Class, BDO = Basic Diving Officer, SO = Salvage Officer, MU = Munitions Officer, 1C = First Class, He-O₂ = He-O₂ Diving Officer, DMT = Diving Medical Technician, DMO = Diving Medical Officer, HT = hydraulic tools. Dives are both air and He-O₂.

*Percentage of male or female divers attending this level of training; many divers attended more than one course. **Deep dives are defined as 4.64 ATA (120 fsw) or deeper. †1C, He-O₂, DMT, and DMO students all perform He-O₂ dives. †Data above *do not* reflect the 18.7% attrition rate that occurred for males nor the 3.4% for females. Four hundred eighty-seven males and 28 females were confirmed as having made deep dives.

(120 fsw), and it is these 878 dives which comprise the two-part deep dive analysis that follows. Air dives accounted for 76.2% of the deep dives, and 23.8% were He-O₂ dives (Table 2). An estimated 988 total dives were completed by women, and 75 of these were deep dives. Sixteen percent of deep dives performed by the women were He-O₂ dives compared to 24.6% for the men.

Each woman averaged 2.58 deep dives while each man averaged 1.73 deep dives. Two observations suggest why the women performed more deep dives per diver than the men. Women divers attended more courses on the average than men (i.e., $\bar{x}_f = 1.68$ to $\bar{x}_m = 1.27$) and, therefore, did more dives. Also, a higher percentage of women attended courses that encompassed He-O₂ training with its emphasis on deep diving [female = 32.3% compared to 25.5% for the men (Table 1)].

No women divers have manifested DCS since NDSTC began training in 1980. In the study group described, 9 men developed symptoms of DCS. Eight of these DCS cases occurred during deep PVA dives at NDSTC; 4 were air and 4 were He-O₂ dives. One male diver suffered DCS while diving at sea to 4.06 ATA (101 fsw) on He-O₂ and, therefore, was not considered in our deep-dive analysis. Six DCS cases were type II serious DCS, and 3 were type I mild DCS (Table 3). The DCS incidence for male deep dives is 1.91% for He-O₂ dives and 0.6% for air dives. Overall the male incidence was 1.0% on deep dives.

Sixty female deep PVA dive profiles were examined in which a total of 158 males were specifically identified as "buddies" of these females. All males underwent the same exact, matched compression-decompression profiles as their female buddies. Again, no DCS cases were diagnosed in the women but 2 of the males experienced DCS, cases 2 and 3 in Table 3. Both of these cases occurred on a single air 9.64 ATA (285 fsw) dry chamber dive. The male DCS rate on this matched analysis was 1.3%.

Binomial statistical analysis of relative female and male DCS incidence rates on deep PVA dives was performed. Both the general DCS analysis and the one-on-one matched analysis with buddy divers demonstrate significantly different results from the fourfold higher incidence of DCS for women found in Bassett's altitude study ($P < 0.05$) (5).

DISCUSSION

Data from NDSTC demonstrate that female divers are at no greater risk of sustaining DCS than males under similar dive exposures. This study must be viewed as

TABLE 2
AIR VS. HE-O₂ BREAKDOWN ON DEEP DIVES CONDUCTED BY THE STUDY GROUP

Dives	Men	(%)	Women	(%)	Totals	(%)
Air	606	(75.4)	63	(84.0)	669	(76.2)
He-O ₂	197	(24.6)	12	(16.0)	209	(23.8)
Totals:	803	(100)	75	(100)	878	(91.5 male) (8.5 female)

Air and He-O₂ dives done in NDSTC PVAs to 4.64 ATA (120 fsw) or deeper. Thirty-nine of the air dives were dry chamber dives.

TABLE 3
DECOMPRESSION SICKNESS CASES IN MALE CLASSMATES OF NDSTC FEMALE DIVERS

Case	Depth, ATA	(fsw)	Time, min	Media	Symptom	Type DCS
1	6.61	185	10	air	elbow pain	I
2	9.64	285	10	air	dizziness, unsteady	II
3	9.64	285	10	air	hip weakness	II
4	9.64	285	10	air	shoulder pain	I
5*	4.06	101	20	He-O ₂	foot paresthesia	II
6	5.55	150	10	He-O ₂	difficulty concentrating, skin DCS	II
7	7.06	200	10	He-O ₂	leg paresthesia	II
8	10.10	300	10	He-O ₂	leg pain	I
9	10.10	300	10	He-O ₂	knee pain, paresthesia	II

*Case 5 occurred in 4.06 ATA (101 fsw) at sea and thus did not meet the criterion for inclusion in the deep dive analysis.

TABLE 4
U.S. NAVY FEMALE DIVING DECOMPRESSION SICKNESS CASES
January 1980 to July 1985

Case	Depth,		Time, min	Media	Symptom	Type
	ATA	fsw				
1*				air	itching, extremity pain	I
2	2.82	60	180 (exp)	air	paresthesia, extremity pain	II
3	4.00	99	76 (exp)	air	extremity pain	I

Data were furnished by the Naval Safety Center, Naval Air Station, Norfolk, VA. (exp) = experimental decompression profile. None of these cases occurred at NDSTC.

*Case number 1 occurred in a woman acting as inside tender on a U.S. Navy Treatment Table 6, depth 2.82 and 1.91 ATA (60 and 30 fsw) for a total of 4 h 45 min.

supportive data dispelling the notion that women are more susceptible to diving DCS than men. However, caution must be taken not to generalize the results of this study beyond what the data will support.

Navy women have sustained diving-related DCS. The reported cases occurred on long-duration, experimental, or saturation dive profiles (Table 4). Indeed, these types of dive profiles have much in common with the altitude exposures investigated by Bassett (1). Altitude DCS occurs when subjects that are essentially saturated at 1 atm total pressure are decompressed to a lesser pressure, causing significantly high inert gas supersaturation in all theoretical tissue compartments. This total supersaturation can also occur on ascent from saturation or long-duration dives. In a

typical dive of short duration only selected compartments will have excessive or near dangerous levels of inert gas supersaturation (6).

The physiologic difference between short- and long-duration dives may very well explain why women at NDSTC are not at a greater risk of sustaining diving-related DCS than the men. In all likelihood, these data can be applied to the general sport scuba diver as well. Women in sport diving who adhere to the U.S. Navy Decompression Schedules and who have dive times less than 1 h are not going to experience inert gas supersaturation at any higher level than women in this study. Therefore, if any increased susceptibility to DCS does exist for female sport divers it will be minimal and should not be a deterrent to women diving on the same decompression schedules as men.

Saturation, experimental, and multiple repetitive dives may prove to be different situations, as was mentioned in the preceding discussion on supersaturation. On these long-duration dives, compartments that absorb and eliminate gas slowly will have a major influence on safe decompression rates. Adipose tissue (i.e., fat) is considered one of the body tissues that tends to be slow in this absorption-elimination process. Adipose tissues hold up to 5 times more inert gas than aqueous tissues (7). In addition, a greater percentage of body fat correlates positively with a higher susceptibility to DCS (8).

Adipose tissue is more predominant in women, with the average woman having a body fat composition approximately 11% greater than the average man (9). This could explain why women exposed to altitude have been shown to have a fourfold greater risk of sustaining DCS than men and is a possible area for future research (1). Likewise this increased adiposity in women may have a positive correlation to DCS incidence on long-duration or saturation diving. This question is not likely to be settled until more women have completed enough long-duration or saturation dives to permit analysis.

As in Bassett's altitude study, this analysis of DCS incidence in NDSTC women divers should be repeated in 5–10 yr. The repeated analysis will benefit from more refined statistics based on the increased data available at that time.

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The opinions and assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.—*Manuscript received December 1986; revision received March 1987.*

Zwingelberg KM, Knight MA, Biles JB. *Maladie de décompression chez les plongeurs.* Undersea Biomed Res 1987; 14(4):311–317. L'incidence comparative de la DCS chez les femmes a été un sujet de discussion pendant bien des années. Les données des carnets de plongée du Naval Diving and Salvage Training Centre (NDSTC), Panama City, Floride, démontrent que le risque de maladie de décompression n'est pas plus élevé parmi les plongeurs de la Marine comparativement à leurs collègues mâles. Vingt-huit étudiantes furent comparées à leurs 487 confrères au cours de 878 plongées à l'air et à un mélange d'hélium-oxygène entre 4.64 et 10.10 ATA (120–300 fsw). Aucune des femmes n'éprouva une DCS tandis que 8 hommes développèrent des symptômes de DCS. La durée totale des plongées varia entre 8 min et 2 h 6 min; les temps de séjour au fond furent moins de 20 min. La supersaturation théorique en gaz inertes sur ces profils est proportionnelle à celle éprouvée au cours de plongée sportives scuba de 40–60 min.

maladie de décompression
mal de caisson
tissus adipeux

les femmes et la plongée
tables de décompression
hélium-oxygène

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