

# **MILITARY FREE-FALL PARACHUTING AFTER DIVING PROJECT REPORT**

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## **ABSTRACT**

The risk of decompression sickness (DCS) increases when flying follows diving. Male volunteers completed simulated 60 ft/60 min dives followed by three hours at 25,000 ft to determine safe surface intervals (SI). Oxygen was breathed for 30 min prior to and throughout flight. Three cases of DCS occurred in 155 exposures (1/35: three hour flight only; 1/37: 18 h SI; 1/36: 12 h SI). These results indicate that the dive tested plus 12 h SI plus altitude exposure may be as safe as the altitude exposure alone. This suggests that the 24 h SI required for U.S. military operations may be conservative. Further work is required to test shorter surface intervals and different dive/flight profiles and to quantify the effects of oxygen breathing.

Keywords: decompression sickness, flying after diving, oxygen breathing

## **INTRODUCTION**

The risk of decompression sickness (DCS) associated with underwater diving is well recognized. The risk of DCS during rapid travel to altitude also exists, particularly if the excursion follows diving activity (Edel et al., 1969; Balldin, 1980; Vann, 1989). Flying after diving guidelines have been proposed based on limited data, most of which pertains to altitude exposures of less than 16,000 ft (Bassett, 1982; Sheffield, 1990; Farr, 1991).

Special Operations personnel engage in Military Free-Fall (MFF) Parachute operations as well as diving operations. Since MFF can entail altitude exposures at 25,000 ft or more, engaging in MFF too soon after diving may substantially increase the DCS risk. The available data are insufficient to establish definitive rules to regulate exposure. Current operational guidelines employed by the U.S. military call for a 24 hour interval to be spent at 1 ata following diving before altitude exposure for MFF. The degree of conservativeness provided by this guideline is unclear. The current study was designed to determine if the obligatory 24 hour post-dive surface interval is necessary and adequate and to collect data which may be used in an ongoing effort to construct a probabilistic model that can evaluate the decompression sickness risk associated with flying after diving activities.

## **METHODS**

### Participants

Participants were male volunteers, certified SCUBA divers or experienced in hyper/hypobaric exposures. Women were excluded so the study population was consistent with U.S. Special Operations Command personnel (gender restrictions limit males to the operational setting). The initial plan was for participants to be recruited from the pool of active duty military personnel. Low military personnel recruitment in the first year (trials scheduled for September 1999 through June 2000) prompted a change in the protocol to allow enrollment of civilians (September 2000 to June 2001). Participants were only allowed to complete a given dive-surface interval-flight profile once, but they were able to complete different profiles.

Each participant received a complete neurological exam immediately prior to the study.

There were no direct benefits to the participants other than the knowledge they gained as a result of their involvement. They were reimbursed for their time and transportation. Meals were provided during the course of the study. Lodging were covered for subjects who live more than one hour from Duke University.

Descriptive measures included standard measures of height, weight and body mass index (BMI). Maximum aerobic capacity was predicted ( $VO_{2 \text{ max pred}}$ ) for civilian participants as part of the standard medical history form completed prior to participation. The Houston non-exercise procedure uses variables of gender, age, BMI and self reported physical activity patterns (0-7 scale) in this computation (Jackson et al., 1990). The reported correlation of  $\sim 0.78$  with measured  $VO_{2 \text{ max}}$  values agrees with our experience using the technique in the laboratory. Reports of physical activity patterns were not collected from the military volunteers.

### Exposure Profiles

Study profiles were conducted as a closely monitored sequence of dive, surface interval (SI) and flight. A single, simulated dive (dry, resting conditions in a hyperbaric chamber) to 60 fsw for 60 min (the no decompression limit of the U.S. Navy Standard Air Decompression tables) was employed. Dives were followed by a series of test preflight surface intervals. The initial preflight surface interval was 24 hours. Participants breathed oxygen for 30 min at ground level (398 feet above sea level) at the end of the surface interval prior to and throughout a simulated flight of three hours at 25,000 feet (a common MFF training altitude).

The travel rate for dives (ascent and descent) was 30 feet per min (fpm) and for flights (again, ascent and descent) was 2,500 fpm. Doppler ultrasound was used to monitor participants non-invasively at 30 min intervals post-dive until bubbles could no longer be detected. Doppler monitoring was conducted at 30 min intervals throughout and following flight until bubbles disappeared. A medical watch was maintained for four hours following flight.

Prior to conducting any dives, the 25,000 ft altitude exposure was tested alone to determine a baseline DCS incidence for evaluating the effect of diving in later studies.

### Doppler Monitoring

A technician was present inside the chamber during all pressure exposures to assist the participants in their activities, conduct Doppler monitoring, and to closely observe individuals for signs and symptoms of DCS or unusual behavior. Technicians would only participate in one of either the dive or flight phase for a given study. For simulated flights, the technician was

required to prebreathe 100% oxygen for three hours prior to altitude exposure and to continue breathing 100% oxygen for the duration of the experiment.

Participants were monitored with Doppler ultrasound (Techno Scientific Inc., Model DBM9008 with Model TSI-DPA7 2.5 MHz Continuous Wave Precordial Probe) by a trained technician. Venous gas emboli (VGE) grades were recorded on a scoring form and the audible signal and technician voice annotations were recorded on cassette tape using a Pioneer CTW340 Cassette Deck. VGE were graded according to the standard Spencer 0-IV bubble grade scale (Spencer, 1976) for compatibility with other laboratories.

Grade 0: The complete lack of bubble signals in all cardiac cycles.

Grade I: The occasional bubble signal detected in a cardiac cycle with the majority of cardiac cycles free of bubble signals.

Grade II: When many, but less than half, of the cardiac cycles contain bubble signals.

Grade III: When most of the cardiac cycles contain bubble signals, but not overriding the cardiac motion signals.

Grade IV: When bubble signals are detected continuously through the cardiac cycles such that the signal overrides the amplitude of the cardiac motion and blood flow signals.

Participants were monitored precordially while maintaining a seated position. Initial measures during motionless sitting (Rest case) were followed by measures recorded during sequential limb movements (Movement case). The participant flexed each limb twice in sequence to mobilize gas bubbles lodged in venous capillaries. The movement case improved the ability to detect VGE. The sequential movements improved the ability to localize the regional source of VGE.

### Medical Monitoring

Physicians were available throughout the study. They were responsible for: (a) performing pre-experiment physical and neurological examinations; (b) verifying the presence or absence of symptoms post-dive, pre-flight, and 30 min, four hours, morning following and 48 hours post-

flight; and (c) diagnosing and treating possible incidents of DCS. Medical checks were conducted in the lab through the morning-following-flight evaluation. The final 48 hour post-flight medical check was completed via telephone. Chamber staff remained on call throughout the study and follow up period in the event that therapeutic recompression was required.

Participants were asked to avoid diving, flying or other altitude exposure and intense or jarring physical activity for 48 hours post-flight to minimize the risk of confounding.

If a subject developed persistent signs or symptoms suggestive of decompression sickness (DCS) while at altitude, he was separated from the others and recompressed to sea level and treated with hyperbaric oxygen. Subjects who remained incident-free but did not complete the three hour flight were not included in the statistical analysis or in decisions of whether to accept or reject a profile.

DCS was classified as mild, moderate, or severe based on the following criteria for the purposes of accepting or rejecting a profile for further testing:

Mild: fatigue; joint pain or muscle aches; minor numbness or paresthesia without objective neurological findings.

Moderate: minor numbness or paresthesia with objective sensory findings. Minor motor weakness without major gait or balance disturbances.

Severe: major numbness or paresthesia with objective sensory findings; major motor weakness; gait or balance disturbance; vertigo; hearing abnormalities; visual disturbance; disturbance of consciousness; cognitive or psychomotor change.

#### Accept/Reject Criteria

The accept and reject criteria were based on statistical estimates of confidence intervals for observations of DCS as part of the study design. These criteria allowed the minimal number of trials to be used to determine if the DCS incidence was sufficiently low to accept a surface interval or was too high to continue testing. They do not necessarily represent risk estimates for

operational exposures. Profiles were accepted for the purposes of the study when there was 95% confidence that the true incidence of DCS was less than 12%. Profiles were to be rejected when there was 95% confidence that the real incidence of DCS was greater than 4%. These rules were the same, with one exception, as those employed in moderately large scale (802 person-exposures) recreational flying after diving study recently completed in our laboratory. The exception was that two moderate incidents (instead of one) were required for profile rejection in the current study.

<b>Accept</b>	<b>Reject</b>
0 DCS incidents in 23 trials	2 moderate incidents at any time
1 mild incident in 35 trial	2 mild incidents in 10 trials
2 mild incidents in 46 trials	3 mild incidents in 26 trials
3 mild incidents in 56 trials	4 mild incidents at any time

Individual trials that ended prematurely were not used in the computation of totals for accept/reject decisions if the reported symptoms were subsequently determined to not be DCS. Doppler data were used from all trials.

Each experiment could include as many as six participants. At the end of each experiment, the preflight surface interval under consideration was evaluated for further testing based upon the trials completed and the classification of any incidents that occurred. Three alternatives were possible: (1) to accept the surface interval without additional testing and begin testing a six hour shorter surface interval; (2) to reject the surface interval without further testing and begin testing a six hour longer surface interval or a different dive profile; or (3) to continue testing the same surface interval.

### Statistical Analysis

Results are reported as means  $\pm$  standard deviation (SD) with ranges as appropriate. One way analyses of variance were used to compare differences in VGE onset and maximum values as a function of post-dive surface interval. Significance was accepted at  $p < 0.05$ .

## RESULTS

A total of 103 individuals participated in the study. This included 21 active duty military personnel in the first year and 82 civilians (80%) in the second year. Participants could be tested only once on a given profile but they could be tested on different profiles. Individuals enrolled for testing on as many as five study profiles (80 individuals - 1 profile, 8 - 2 profiles, 4 - 3 profiles, 6 - 4 profiles, 5 - 5 profiles). There were a total of 160 enrollments registered. Enrollment was defined as completing a consent and registration form and undergoing a screening physical exam. Approximately 97% of the enrollments (155/160) resulted in completed studies. Five enrollments (five different civilians) failed to result in completed studies: two cases of barotrauma during dive, one medical disqualification, one no show for flight, and one case of technical error preventing flight (when air was inadvertently breathed instead of oxygen during 30 min prebreathe period).

Descriptive characteristics for the enrollments appear in Table 1.

Table 1: Descriptive Characteristics of all Enrollments

<b>COMPLETE (155)</b>	Age (y)	Height (m)	Weight (kg)	BMI (kg·m <sup>-2</sup> )	VO <sub>2</sub> max pred (mL·[kg·min] <sup>-1</sup> )
Mean	33.0	1.80	84.5	26.2	---
SD	8.7	0.08	13.8	4.2	---
Range	19.7-57.8	1.42-1.98	61.8-122.7	19.7-44.5	---
<b>MILITARY (21)</b>					
Mean	34.0	1.78	84.7	27.0	N/A <sup>1</sup>
SD	7.5	0.09	11.4	3.9	N/A <sup>1</sup>
Range	23.6-57.8	1.52-1.96	70.5-108.2	21.7-39.1	N/A <sup>1</sup>
<b>CIVILIAN (134)</b>					
Mean	32.9	1.80	84.5	26.1	44.5
SD	8.9	0.08	14.1	4.2	7.7
Range	19.7-50.9	1.42-1.98	61.8-122.7	19.7-44.5	25.5-45.5
<b>INCOMPLETE (5)</b>					
Mean	27.8	1.77	87.7	28.1	39.7
SD	9.2	0.06	16.7	6.6	9.6
Range	20-42	1.70-1.83	75.0-113.6	22.4-39.3	27.5-50.2

N/A<sup>1</sup> - self reports of physical activity patterns not available for VO<sub>2</sub>max prediction

Race characteristics of participants appear in Table 2.

Table 2: Race Characteristics of Participants

	Asian	Black	Hispanic	White
<b>COMPLETED STUDY (103)</b>	4	2	4	92
<b>MILITARY (21)</b>	0	0	1	20
<b>CIVILIAN (82)</b>	4	2	3	73
<b>RELEASED FROM STUDY (5)</b>	1	1	0	3

Five profiles were tested during the study. Two were flight-only control exposures, first a two hour flight duration, then a three hour flight. The next three were complete dive/surface interval/flight profiles. Surface intervals of 24, 18 and 12 hours were tested.

VGE data are summarized in Table 3. VGE were detected in 8% (84/1018) of the monitoring sessions. They were observed with movement only in 79% of the cases (66/84) and with both rest and movement in 21% of the cases (18/84). VGE were never observed during rest only.

Table 3: VGE Summary

Profile	VGE Grade	Max Post-Dive (n [%])	Max During Flight (n [%])	VGE Onset During Flight (min)		Max VGE Onset During Flight (min)	
<b>2 hr FLIGHT ONLY</b>	0		27 [77]	Mean	68.1	Mean	75.8
	1		3 [9]	SD	38.4	SD	31.2
	2		5 [14]				
	3		0 [0]				
	4		0 [0]				
	n		35		8		8
<b>3 hr FLIGHT ONLY</b>	0		18 [75]	Mean	83.8	Mean	102.0
	1		2 [8]	SD	45.9	SD	42.9
	2		0 [0]				
	3		0 [0]				
	4		4 [17]				
	n		24		6		6
<b>24 hr SI DIVE-FLIGHT</b>	0	18 [78]	18 [78]	Mean	68.2	Mean	118.8
	1	2 [9]	1 [4]	SD	35.4	SD	27.2
	2	2 [9]	1 [4]				
	3	1 [4]	0 [0]				
	4	0 [0]	3 [13]				
	n	23	23		5		5
<b>18 hr SI DIVE-FLIGHT</b>	0	37 [100]	31 [84]	Mean	89.4	Mean	89.4
	1	0 [0]	4 [11]	SD	26.9	SD	26.9
	2	0 [0]	0 [0]				
	3	0 [0]	1 [3]				
	4	0 [0]	1 [3]				
	n	37	37		5		5
<b>12 hr SI DIVE-FLIGHT</b>	0	34 [94]	29 [81]	Mean	100.4	Mean	119.7
	1	1 [3]	0 [0]	SD	39.4	SD	52.6
	2	1 [3]	4 [11]				
	3	0 [0]	1 [3]				
	4	0 [0]	2 [6]				
	n	36	36		7		7
<b>OVERALL</b>	0	89 [93]	124 [80]	Mean	81.9	Mean	99.9
	1	3 [3]	9 [6]	SD	38.0	SD	40.1
	2	3 [3]	10 [6]				
	3	1 [1]	2 [1]				
	4	0 [0]	10 [6]				
	n	96	155		31		31

VGE were observed post-dive in 7% (7/96) of the exposures and during flight in 20% (31/155) of the exposures. Five of the seven cases with post-dive VGE had no observed VGE during the subsequent flight. VGE of grades 3 or 4 were observed post-dive in 1% (1/96) of the exposures and during flight in 8% (12/155) of the exposures. Grades 3 and 4 VGE were seen during flight with studies of each of the surface interval profiles (3/23 exposures [13%] for 24 hour SI trials; 2/37 [5%] for 18 hour SI trials; 3/36 [8%] for 12 hour SI trials).

VGE patterns can also be summarized by the number of individuals participating instead of the number of exposures. VGE were observed post-dive in 9% (6/68) of the participants and during flight in 40% (27/68) of the participants. Three of the six cases with post-dive VGE had no observed VGE during the subsequent flight. VGE of grades 3 or 4 were observed post-dive in 4% (3/68) of the participants and during flight in 19% (20/103) of the participants.

Mean onset time for in-flight VGE was  $82 \pm 38$  min. There were no differences in onset time between the five profiles tested ( $p=0.88$ ). The mean time to max VGE was  $100 \pm 40$  min with no clear pattern related to surface interval duration. Again there were no differences in time to maximum VGE between the five profiles tested ( $p=0.68$ ).

There were no reports of symptoms during or following the dive phase of the study. There were eight reports of symptoms during the flight phase. Three resulted in shortened flights for the affected individuals; two cases of which were ultimately diagnosed as DCS and one as unrelated symptoms. The flights were completed in five cases; with one case ultimately diagnosed as DCS and four as unrelated symptoms.

The three cases of DCS diagnosed through the study (1.9% incidence) were distributed throughout the profiles (Table 4). One occurred during the two hour flight-only profile; one during the flight following the 18 hour surface interval; one during the flight following the 12 hour surface interval. All three were pain only DCS and were completely resolved with no residual. The two hour flight-only case was not treated because it was not reported until after the flight at which time there were no symptoms. The 18 hour surface interval case was treated with

two hours of surface oxygen post-flight and retreated with a USN Treatment Table 5 the morning after the flight. The 12 hour surface interval case was treated with a USN Treatment Table 5 post-flight.

Table 4: Symptoms Reported During Flight Phase of Study

Profile	Person-Trials	DCS Symptoms (n [%])	Non-DCS Symptoms (n [%])
2 h Flight Only	35	1 [2.9]	
3 h Flight Only	24		1 [4.1]
60'/60 min Dive + 24 h SI + Flight	23		
60'/60 min Dive + 18 h SI + Flight	37	1 [2.7]	3 [8.1]
60'/60 min Dive + 12 h SI + Flight	36	1 [2.8]	1 [2.8]
TOTAL	155	3 [1.9]	5 [3.2]

The VGE scores of the individuals presenting with DCS appear in Table 5. Case history details appear in Appendix 1.

Table 5: VGE Summary for Participants Developing DCS

Profile	Max VGE Post-Dive	Max VGE During Flight	VGE Onset During Flight (min)	Max VGE During Flight (min)	Symptom Onset During Flight (min)
3 hr Flight Only 1-1	---	0			60
18 hr SI Dive-Flight 1-2	0	0			90
12 hr SI Dive-Flight 1-3	0	2	38	38	30

The VGE scores of the individuals presenting with symptoms classified as not being DCS appear in Table 6. Case history details appear in Appendix 2.

Table 6: VGE Summary for Participants with Symptoms Classified as Not Being DCS

Profile	Max VGE Post-Dive	Max VGE During Flight	VGE Onset During Flight (min)	Max VGE During Flight (min)	Symptom Onset During Flight (min)
3 hr Flight Only 2-1	---	1	111	111	60
18 hr SI Dive-Flight 2-2	0	0			105
18 hr SI Dive-Flight 2-3	0	0			150
18 hr SI Dive-Flight 2-4	0	0			150
12 hr SI Dive-Flight 2-5	0	0			90

## DISCUSSION

The anthropometric data summarized in Table 1 suggest that the civilian participants were at least superficially similar to the military personnel initialing volunteering for the study.

Our data suggest that an obligatory 24 hour surface interval may be unnecessarily conservative for current military freefall operations to 25,000 ft following a single, 60 fsw for 60 min diving exposure. We were able to accept 24, 18 and 12 hour surface intervals with no more than one case of DCS out of 36 person-trials.

There are a number of issues that remain to be resolved. The first is that we cannot say that 12 hours is the shortest safe surface interval following this diving exposure since we were not able to test shorter intervals within the study period. While the diving exposure employed was at the no-decompression limit of the U.S. Navy tables, they represent only one example. We do not know if the results would be similar with repetitive diving or decompression diving. In addition, the current study did not attempt to quantify the effect of the oxygen prebreathe on decompression risk by testing exposures without the prebreathe. It is likely that the oxygen breathing period reduced the risk but additional work is required to answer this question

definitively. Finally, the current study had an insufficient number of cases of DCS to facilitate the development of probabilistic models.

#### Recommendations for Operational Guidelines

Reduce the required preflight surface interval following single, no decompression dives from 24 hours to 12 hours. More conservative guidelines may be desirable for preflight surface intervals following repetitive or decompression diving.

#### Recommendations for Continued Work

Continue the current testing program to determine the shortest effective surface interval able to protect against DCS associated with 25,000 ft exposure following a dive to 60 fsw for 60 min. Confidence in a decision to reduce the required surface interval would be improved by identification of the surface interval at which a clearly increased rate of DCS occurs.

We recommend that surface interval shortening is limited to a rate of three hours per step for subsequent steps below 12 hours. This will reduce the likelihood of observing a dramatic increase in DCS incidence per step. The DCS events that are recorded will provide necessary data for the construction of computer models.

#### Recommendations for Future Work

Additional studies should be conducted to investigate the response to pre-flight repetitive and decompression diving and to quantify the effect of oxygen prebreathe on decompression safety.

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## APPENDIX 1

### Case Histories of Symptoms Classified as DCS

#### Incident #1-1

Profile: 2 h 25,000 ft flight only (control exposure); 9/29/99

Subject: Healthy, 31 year old white male, active duty Army diver, Ht = 1.73 m, Wt = 75.0 kg, BMI = 25.1 kg·m<sup>-2</sup>.

Presentation: After approximately one hour into a two hour simulated flight he began to experience a sharp, steady pain in the dorsum of his right foot described as a 3/10 pain level. He did not report the discomfort to the inside tender. The pain continued to increase to the 7/10 level over the next hour. He still failed to report the discomfort to the tender. He began to have relief of his symptoms on recompression to the surface. He had complete resolution of pain on reaching the surface. He denied any other symptoms. He reported symptoms during the post-flight medical check, 30 min post-flight.

Evaluation: Normal neurological exam and no pain in affected area post-flight. Continued asymptomatic two, four and 24 hours post-flight.

#### Incident #1-2

Profile: 60'/60 min dive + 18 h SI, 3 h 25,000' flight; 2/7-8/01

Subject: Healthy, 27 year old white male medical student, Ht = 1.80 m, Wt = 70.5 kg, BMI = 21.7 kg·m<sup>-2</sup>, Houston Non-Exercise Predicted VO<sub>2 max</sub> = 45 mL·kg<sup>-1</sup>·min<sup>-1</sup>. Hay fever allergy treated with Claritin.

Presentation: Reported sharp, steady but progressing right knee pain (initially 1-2/10 and sharp progressing to 3-4/10 and more steady, a little worse with joint flexion and extension [5/10 at worst]) at 1h:45 into a three hour simulated flight. Occasional twinges of similar pain in right ankle but most in knee. The subject was transferred into a second chamber at altitude and returned to ground level. Symptoms resolved at 5,000 feet simulated altitude during compression. Treated with two hours of 100% oxygen at the surface delivered through a head tent.

Follow Up Events: The subject returned to the lab on the morning following flight to report a reoccurrence of discomfort in his right knee at approximately 2330 on the previous evening (~11.5 hours post-flight). He described the sensation as intermittent soreness, 1/10 in severity, more noticeable with walking. A U.S. Navy Table 5 treatment was conducted. His symptoms resolved completely within one minute at a depth of 60 feet. Continued asymptomatic post-treatment and at 24 hour follow up.

#### Incident #1-3

Profile: 60'/60 min dive + 12 h SI, 3 h 25,000' flight; 4/13/01

Subject: Healthy, 39 year old white male, Ht = 1.73 m, Wt = 80.9 kg, BMI = 27.1 kg·m<sup>-2</sup>, Houston Non-Exercise Predicted VO<sub>2 max</sub> = 43 mL·kg<sup>-1</sup>·min<sup>-1</sup>. No known allergies.

Presentation: Reported 'achy' feeling in right elbow at 0h:30 progressing to bilateral elbow pain (5/10 [spiking to 6/10] in severity) by 0h:45 into a three hour simulated flight. Symptoms resolved before compression to ground level was complete. A U.S. Navy Table 5 treatment was conducted after evaluation. Continued asymptomatic through treatment, post-treatment and at 24 hour follow up.

## APPENDIX 2

### Case Histories of Symptoms Classified as Not Being DCS

#### Incident #2-1

Profile: 3 h 25,000' flight only (control exposure); 10/4/00.

Subject: 28 year old white male, Ht = 1.83 m, Wt = 79.5 kg, BMI = 23.8 kg·m<sup>-2</sup>, Houston Non-Exercise Predicted VO<sub>2 max</sub> = 50 mL·kg<sup>-1</sup>·min<sup>-1</sup>

Presentation: Dull pain in back of right thigh, grade 1/10, started at 60 min into simulated flight, lasted for final two hours of flight, positional. Attributed to seating.

#### Incident #2-2

Profile: 60'/60 min dive, 18 hr SI, 3 h 25,000' flight; 2/2/01.

Subject: 48 year old white male, Ht = 1.75 m, Wt = 67.3 kg, BMI = 21.9 kg·m<sup>-2</sup>, Houston Non-Exercise Predicted VO<sub>2 max</sub> = 46 mL·kg<sup>-1</sup>·min<sup>-1</sup>

Presentation: Sharp, right groin pain, grade 3/10, started at 105 min into simulated flight, lasted <10 min, relieved by stretching and did not return, subject finished exposure. Attributed to position while seated.

#### Incident #2-3

Profile: 60'/60 min dive, 18 hr SI, 3 h 25,000' flight; 2/16/01.

Subject: 20 year old white male, Ht = 1.75 m, Wt = 77.5 kg, BMI = 25.2 kg·m<sup>-2</sup>, Houston Non-Exercise Predicted VO<sub>2 max</sub> = 54 mL·kg<sup>-1</sup>·min<sup>-1</sup>

Presentation: Numbness in tips of both little toes and numbness and tingling (1/10) in tips of both little fingers, started at 150 min into simulated flight. Tingling in finger progressed to entire finger, no symptoms in hand. Symptoms lasted 10 min, resolved spontaneously at altitude and did not return, subject finished exposure. Attributed to hyperventilation from anxiety.

#### Incident #2-4

Profile: 60'/60 min dive, 18 hr SI, 3 h 25,000' flight; 2/16/01.

Subject: 25 year old Asian male, Ht = 1.70 m, Wt = 84.1 kg, BMI = 29.0 kg·m<sup>-2</sup>, Houston Non-Exercise Predicted VO<sub>2 max</sub> = 47 mL·kg<sup>-1</sup>·min<sup>-1</sup>

Presentation: Right shoulder pain (2/10 in severity), started at 150 min into simulated flight, lasted 10 sec, resolved at altitude did not return, subject finished exposure. Determined to be unrelated to pressure exposure, history of similar experiences.

#### Incident #2-5

Profile: 60'/60 min dive, 12 hr SI, 3 h 25,000' flight; 5/31/01.

Subject: 44 year old white male, Ht = 1.78 m, Wt = 84.1 kg, BMI = 26.6 kg·m<sup>-2</sup>, Houston Non-Exercise Predicted VO<sub>2 max</sub> = 44 mL·kg<sup>-1</sup>·min<sup>-1</sup>

Presentation: Left shoulder pain, 1-4/10 in severity, started at 90 min into simulated flight, lasted 60 min, resolved at altitude. Subject was brought out of the chamber, unrelated to pressure exposure. Attributed to stiffness due to being seated for a long period; history of similar experiences.