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ANALYSIS OF THE INDIVIDUAL RISK OF ALTITUDE DECOMPRESSION SICKNESS UNDER REPEATED EXPOSURES

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ABSTRACT: In a case-control study, we examined the risk of Decompression Sickness (DCS) in individual subjects with higher number of exposures. Of 126 subjects (mean [SD]) of age 31.2 (7.2) years, body mass index 16.0 (4.2) and 2.7 (2.5) exposures each, 42 (33%) showed one or more episode of DCS. Examination of exposure-DCS relationship by odds ratio (OR) showed a linear relationship (r=0.98). The risk of DCS, when number of exposures >3, was 3.7 times (95% confidence interval 1.8,8.7) greater than ≤3 exposures in the individual. Stratification analyses showed that sex, tissue ratio (360-min half-time) and presence of Doppler microbubbles were confounders of this risk. Higher number of exposures increased the risk of DCS in our analysis.

INTRODUCTION : Decompression Sickness (DCS) is the result of a series of pathophysiological processes to acute changes in ambient pressure. There is considerable evidence that some individuals are more susceptible than others ("resistant") to DCS. Further, some authors believe that there is adaptation to DCS stress with repeated exposures.

The problem is twofold: First, what is the risk of DCS in individuals who are exposed many number of times compared to individuals with one or two exposures? Second, what is the risk of DCS in individuals on subsequent exposures? The latter is the question of adaptation or acclimatization and has been investigated by many.

In this paper, we analyze the risk of DCS in individuals with higher number of exposures in the various experiments conducted at NASA Johnson Space Center, Houston, TX, involving simulated extravehicular activities (EVA).

METHODS AND RESULTS :

Information on 126 healthy, individuals (101 males, 25 females), who participated in a total of 345 exposures to

reduced pressure were collected. The exposures involved both direct and staged decompression profiles. The individuals exercised at altitude simulating extravehicular activities (6). They were also monitored for the presence of circulating microbubbles (CMB) by a precordial Doppler monitor. The exposure pressure and pre-breathe times were expressed as a 360-minute half-time tissue ratio (TR) (2). All exposures were for a period of 3 to 6 h at altitude. Further details on these profiles may be obtained elsewhere (2,6).Subjects were also required to rate their activities on a scale of 1-10, for assessment of fitness levels. Individual baseline characteristics were as below (mean[SD]):

Age	31.2 (7.2) yrs
Body mass index	16.0 (4.2)
No. of exposures	2.7 (2.5)
Tissue Ratio (360-minute)	1.5 (0.2)

Symptoms occurred in 56/345 (16%) of these exposures, of which only 4% (2/56) were severe or Type II DCS, the rest being pain-only bends. Forty-two individuals presented the 56 episodes of symptoms as below:

Once = 30 (71%)
Twice = 10 (24%)
Thrice = 2 (5%)

Distribution of cases (mean[SD]) with and without any symptom occurrence is given in Table I.

The number of exposures in individuals with and without symptoms was significantly different (Table I). Hence, we divided the entire group based on ≤3 and >3 exposures (Table II).

Table I. Distribution of cases

	No symptoms (n=84)	Symptoms (n=42)	
Age-years	30.5 (0.8)	32.5 (1.1)	
BMI	15.7 (0.5)	16.5 (0.6)	
TR	1.5 (0.1	1.6 (0.1)	*
No. of exposures	2.3 (0.3)	3.6 (0.4)	*
No. runs with CMB	0.6 (0.1)	2.1 (0.2)	*
Sex			
Male	61	40	*
Female	23	2	
Fitness scores			
≤5	48	19	
>5	36	23	

BMI=body mass index; * p<0.05

Table II. Subgroup on Exposure

	≤3 exp (n=100)	>3 exp (n=26)	
Age-yrs	31.3 (0.7)	30.6 (1.3)	
BMI	15.7 (0.4)	17.0 (0.6)	
TR	1.5 (0.1)	1.5 (0.1)	
No. of exposures	1.7 (0.8)	6.9 (2.7)	*
No. of runs with CMB	0.8 (0.0)	2.5 (0.4)	*
Sex			
Male	75	26	*
Female	25	0	
Fitness scores			
≤5	51	16	
>5	49	10	

* p<0.05

We calculated the odds ratio (OR) or cross-product ratio as a measure of relative risk of symptoms with higher exposure numbers in individuals (3). The results are given in Fig. 1.

Compared to occurrence of symptoms in individuals with single hypobaric exposure, there was greater risk of DCS in individuals with higher number of exposures. This increase in risk was linear (r=0.98). However, these findings were limited by the sample size, hence the wide confidence intervals (CI).

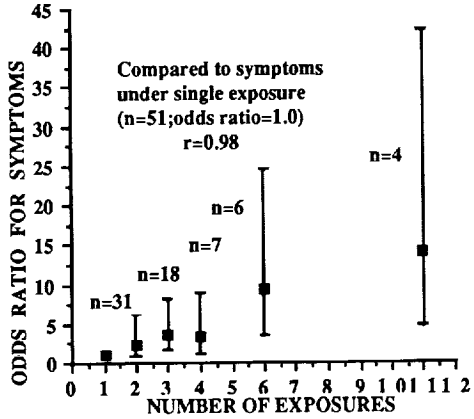

Fig. 1. Risk of symptoms with increased exposures

The overall OR for symptoms when the number of exposures were >3, compared to ⩽3 in the individual is given in Table III.

Table III. Individual risk with higher exposures.

	No DCS	DCS	OR
⩽3 exposures	73	27	1.0
>3 exposures	11	15	3.7 (1.8,8.7)

OR=odds ratio; 95% confidence intervals in parentheses.

We also examined the baseline differences (Table II) on the individual exposure information (⩽ and >3 exposures) by stratification analyses and Mantel-Haenszel statistics (3). The results are in Table IV.

Table IV. Stratification Analysis

	No DCS	DCS	OR	OR-MH
1. Sex				
Male :				
⩽3 exp	50	25	1.0	
>3 exp	11	15	2.7	
Female:				
⩽3 exp	23	2	1.0	
>3 exp	0	0	-	2.7 * (0.9,7.5)
2. No. of runs with CMB				
once :				
⩽3 exp	68	11	1.0	
>3 exp	7	2	1.8	
> once:				
⩽3 exp	5	16	1.0	
>3 exp	4	13	1.0	1.3 (0.01,137.5)
3. TR				
⩽1.5 :				
⩽3 exp	43	4	1.0	
>3 exp	8	5	6.7	
>1.5 :				
⩽3 exp	30	23	1.0	
>3 exp	3	10	4.4	5.2 * (1.8,14.7)

OR=odds ratio; OR-MH=odds ratio by Mantel-Haenszel statistic; 95% confidence intervals in parentheses; TR=360-minute half-time tissue ratio; * chi-square $p<0.05$.

DISCUSSION:

The results of the analyses showed that individuals with >3 exposures were 3.7 times more at risk for DCS, compared to individuals with ⩽3 exposures.

Bason et al. observed increased incidence (up to 12-fold) of DCS in the inside observers, compared to hypobaric chamber

trainees (1). They attributed that this greater risk resulted from the higher number of exposures in the observers. Similar examination by Piwinski et al. on USAF data showed that the inside technicians showed a 4.6 times increased risk of DCS (maximum of 41 exposures), compared to students (5). They observed that in addition to the lower number of exposures, trainees were younger in age.

In repeated exposures, Malconian et al. observed that the period of exposure to altitude was also an important factor increasing the risk of DCS in observers (4). All the above studies, however examined only the overall risk and not the individual risk with increased exposures.

In our analysis, we looked at the risk of DCS in a group of healthy individuals who participated in the simulated EVA profiles. Although sex and TR showed higher risk of DCS in individuals with >3 exposures (Table IV), 95% confidence intervals of the crude OR were wide and sample size limited. However, we did not look into the possible effects of interval between exposures and no multivariate analyses were undertaken. More data is being accumulated to include these analyses.

SUMMARY:

Individuals with >3 exposures were at 3.7 times greater risk of DCS in our analysis. Sex, TR and number of runs with Doppler detectable microbbubbles were confounders of this risk. Number of exposures in the individual appears to be an independent risk factor for DCS.

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