DEVELOPMENT OF ANXIETY SYMPTOMS DURING A DEEP DIVING EXPERIMENT

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Six commercial divers were investigated for anxiety responses during a 29-day, open-sea world record dive at 500 meters of depth. Three of six (50%) divers developed anxiety. The authors emphasize the importance of research on personality traits as possible predictors for the development of anxiety during deep dives of exceptional depth and duration of confinement. Anxiety 1:237–241 (1994/1995). *© 1995 Wiley-Liss, Inc.*

Key words: ***anxiety, confinement, High Pressure Neurological Syndrome, pressure, Anxiety Scale Questionnaire***

INTRODUCTION

Divers are exposed to an increase in pressure which is related to the depth of sea water. At sea level, pressure is 0.1 MPa (i.e., 1 atm or 1 bar) ; it increases 0.1 MPa every 10 meters of sea water (msw). Breathing air at depth induces nitrogen narcosis. To avoid this, breathing mixtures which include a diluent gas with a lower narcotic potency than nitrogen have been used. Helium has relatively low narcotic potency and is extensively used, therefore, for deep diving. However, when humans are exposed to environments of more than 150–200 msw in a helium-oxygen breathing mixture, they develop the High Pressure Neurological Syndrome (HPNS); (Lemaire and Rostain, 1988; Bennett and Rostain, 1993). Furthermore, diving beyond 150–200 msw has required divers to live in pressure chambers for several days that include the compression, stay at depth to work, and decompression phases.

Symptoms of the HPNS mainly include nausea, postural and intention tremor, myoclonia, decrements in psychosensorimotor and intellectual performance, and electroencephalographic changes such as an increase in slow frequency activities and sleep disturbances. These signs and symptoms of HPNS have provided a formidable limitation to man's ability to dive to, and work at ocean depths beyond 300–350 msw (Bennett and Rostain, 1993). Presently, the control strategies of HPNS include slow exponential compression with stages, adaptation with time at depth, and the use of narcotic gases, such as nitrogen (Rostain et al., 1980; Bennett et al., 1981) or hydrogen (Rostain et al., 1988; Bennett and Rostain, 1993).

Few studies have evaluated the behavioral effects of diving, particularly dives of exceptional depth. Studies using the Luscher's color test have demonstrated that living in a pressure chamber may induce anxious reactions (Bugat, 1989; Bugat and Lemaire, 1992). Since the development of such anxiety responses has been further suggested to occur in both normal subjects and others showing an anxious guilt (Bugat, 1989), the predictors of diving anxiety remain unclear. Elsewhere, other studies related to space and navy medicine have shown that confinement at normal pressure might also induce anxious reactions in subjects exposed to such conditions (Ruff and Levy, 1959; Nardini et al., 1962). There is therefore some evidence to suggest that depth and/or duration of confinement may contribute to the likelihood of anxiety.

The main purpose of the COMEX-Hydra VIII dive was to demonstrate the operationality of hydrogenated breathing mixtures in an offshore oil installation. We took advantage of this diving exercise to determine whether subjects participating in a dive of such exceptional depth (500 msw) and duration (29 days) would develop symptoms of anxiety.

METHODS

SUBJECTS

Six male commercial divers participated as subjects: 2 from the French navy (D3, and D6) , and 4 from the Comex company (D1, D2, D4, and D5). All of them had previously participated in hydrogen-oxygen (D5) or hydrogen-helium-oxygen (D1, D2, D3, D4, and D6) saturation dives. The ages of the subjects ranged from 32 to 43 years (mean value: 36 years). All gave their full informed consent. The divers were divided into 2 groups: G1 (D1, D2, D3) and G2 (D4, D5, D6), according to personal preference. Subjects lived in interconnected separate pressure chambers of approximately 7 m^2 of surface and 15 m^3 of volume each.

DIVE PROFILE

The profile of the Comex-Hydra VIII experimental dive at sea is shown in Figure 1. Compression was started with helium to 250 msw. At this depth, the

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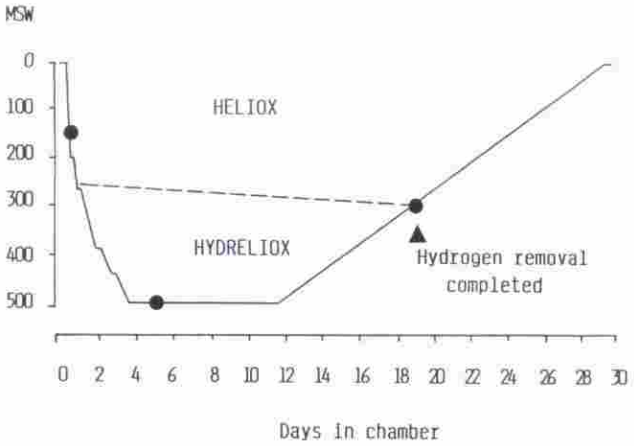

Figure 1: Profile of the Hydra VIII open-sea experimental dive. Compression was performed with helium to 250 meters of sea water (msw). Then, compression was continued with hydrogen to 500 msw, i.e., the depth life level at which the scheduled task was achieved. Decompression was initiated by hydrogen catalytic removal from 500 to 300 msw using a linear rate of 1.2 m/h from 500 to 300 msw. After hydrogen elimination, decompression proceeded as per a standard procedure for heliox saturation from 300 msw to surface using linear rates of 1.2 m/h from 300 to 15 msw, and 1 m/h from 15 msw to surface. Full circles represent time of test sessions using the Cattell's anxiety questionnaire at 140 (day 1) and 500 msw (day 5) on compression, and 320 msw (day 19) on decompression.

compression was continued with hydrogen so that a total compression time of 4 days and 22 h was taken to reach 500 msw, i.e., the depth life level.

A period of 7 days and 17 h was spent at 500 msw to achieve the main objective of the Hydra VIII experimental dive at sea, which was to succeed with the scheduled task, i.e., the connection of specific elements of an oil installation, and therefore to prove the operationality of hydrogenated diving breathing mixtures. During this period, divers transferred to the underwater worksite using a diving bell.

After the scheduled task was achieved, decompression was initiated by hydrogen catalytic removal from 500 to 300 msw. After hydrogen elimination, decompression proceeded per standard procedure for helium-oxygen saturation dives from 300 msw to surface. Decompression was performed using linear rates of 1.2 m/h from 500 to 15 msw, and linear rates of 1 m/h from 15 msw to surface.

The divers emerged from the pressure chambers after 17 days and 11 h of decompression, so that the total confinement time was 29 days, 1 h, 20 min.

EXPERIMENTAL DESIGN

In the present study, the Anxiety Scale Questionnaire (ASQ) was used to assess anxiety levels. Due to operational priorities, there was only four test sessions, which were performed at surface (day –2), during compression at 140 msw (day 1) and at 500 msw (day 5), and during decompression at 320 msw (day 19).

Test sessions were performed at the same hour, between 10:00 and 12:00 a.m. in a testing chamber interconnected to the living chambers. Predive basal measurements (day –2) were used as control values.

ANXIETY SCALE QUESTIONNAIRE

We used the Cattell Anxiety Scale Questionnaire (ASQ) that contains 40 items each scored from 0 to 2. The ASQ provides a raw score of anxiety (range 0–80) and 5 personality factor raw scores with a range of severity from 0–8 (factor L), 0–12 (factor C), 0–16 (factor Q3), 0–20 (factor Q4), and 0–24 (factor 0). Then, according to the ASQ Handbook that provides norms which allow conversion of raw scores into standard scores, both anxiety and personality factor scores were expressed as standard scores (Centre de Psychologie Appliquée, 1962; Krug et al., 1976).

So far as anxiety is concerned, standard scores of 0–3, 4–6, 7–8, and 9–10, reflect, respectively, an ability to tolerate stress, normal levels of anxiety, typical "neurotic" levels of anxiety, and severe anxiety.

STATISTICAL ANALYSIS

Changes in both anxiety and personality factor scores in relation to the depth and the duration of the dive were assessed using a one-way analysis of variance (ANOVA) for repeated measures.

RESULTS

For the whole sample of divers, neither the anxiety score ($F = 1.96$, df = 3, 15, n.s.) nor the following personality factor scores C, O, Q3, and Q4 (C: $F = 1.17$, df = 3, 15, n.s.; O: $F = 1.26$, df = 3, 15, n.s.; Q3: $F = 2.325$, df = 3, 15, n.s.; Q4: $F = 0.94$, df = 3, 15, n.s.) changed during the course of the study. Alternatively, factor L showed a significant increase at 320 msw on decompression (day 19) (L: $F = 4.47$, df = 3, 15, $P < 0.02$). Data are exposed in details in Table 1.

Changes in anxiety for individual divers are presented in Figure 2. Three of them demonstrated modest increases in ratings of anxiety during the study; however, of the six divers, only diver D2 demonstrated clinically relevant levels of anxiety (i.e., "distress neurosis") at any point during the course of the dive.

DISCUSSION

As the main purpose of the present open-sea experimental dive was to demonstrate the operationality of hydrogenated diving breathing mixtures in an offshore oil installation, we used the Cattell Anxiety Scale Questionnaire because this scale only requires short-term test sessions of about 5–10 minutes. Although the ASQ is not as sensitive for evaluating personality features as more specific questionnaires (Krug et al., 1976), such as the objective-analytic personality factor

TABLE 1. Changes in both anxiety and personality factors standard scores in the six divers at surface (day–2), 140 (day 1) and 500 meters of sea water (msw) (day 5) on compression, and 320 msw (day 19) on decompression[a]

Subject	Day and depth	Anxiety	C	L	O	Q3	Q4
D1	d-2, 0 msw	4	7	4	0	7	2
	d1, 140 msw	4	5	4	2	6	4
	d5, 500 msw	5	5	4	3	7	7
	d19, 320 msw	6	7	7	6	6	4
D2	d-2, 0 msw	2	3	4	3	4	0
	d1, 140 msw	1	3	0	2	1	0
	d5, 500 msw	8	10	3	8	5	6
	d19, 320 msw	6	7	6	3	5	8
D3	d-2, 0 msw	0	3	2	0	0	1
	d1, 140 msw	0	0	0	1	1	1
	d5, 500 msw	0	0	2	0	4	0
	d19, 320 msw	0	0	0	0	1	0
D4	d-2, 0 msw	2	7	0	1	3	1
	d1, 140 msw	2	4	2	2	1	3
	d5, 500 msw	1	4	0	0	3	0
	d19, 320 msw	6	5	3	6	6	6
D5	d-2, 0 msw	3	7	4	2	3	2
	d1, 140 msw	2	6	0	0	2	5
	d5, 500 msw	2	3	2	2	2	3
	d19, 320 msw	3	6	4	1	4	3
D6	d-2, 0 msw	0	3	0	0	2	2
	d1, 140 msw	0	0	0	0	0	0
	d5, 500 msw	0	0	0	2	0	0
	d19, 320 msw	0	0	3	0	0	0

[a]*Factors C, L, O, Q3, and Q4 represent the ego weakness, the incapacity to cope with frustration, the depressive anxious guilt, the lack of socially approved behaviors, and the level of frustration, respectively.*

test battery (Cattell, 1955) or the 16 personality factor questionnaire (Cattell, 1956), it is, however, largely considered a reliable scale of general anxiety (Bobbon, 1988).

For the whole sample of divers, our results indicate that factor L showed a significant increase on the last ASQ test session, i.e., on day 19. This suggests that long-term confinement would induce an increase in both suspicion and the incapacity to cope with frustration. For individual divers, our results clearly indicate that only three of the six (50%) divers, D1, D2, and D4, who participated to this open-sea world record dive, developed anxiety symptoms, whereas the others, D3, D5, and D6, showed no anxious reactions. These data are in agreement with previous studies that have previously demonstrated that anxiety responses only occurred, for a given dive, in some subjects (Bugat, 1989; Bugat and Lemaire, 1992).

Since the development of such anxiety responses has been further suggested to occur in both normal subjects and others showing an anxious guilt (Bugat, 1989), the predictors of diving anxiety remain unclear. However, it can be speculated with little doubt that if either depth of diving or duration of confinement were the primary reasons for the development of anxious reactions, most or all of the divers participating in this world record dive would have reported an increase in ratings of anxiety. As this was not the case, our results suggest that factors other than depth or confinement have contributed to the development of anxiety in divers D1, D2, and D4 during the present experimental dive.

The dimension of introversion-extroversion has been mentioned as a factor explaining why some volunteers are unable to stand experimental confinement (Miyashiro and Russel, 1974), and pioneer experiments have clearly demonstrated that normal non-neurotic subjects might develop anxiety during stressful situations, according to some personality traits, such as the incapacity to control and express tensions in an appropriate manner (ego weakness), the incapacity to cope with frustrations (suspicion), the depressive anxious guilt, the lack of socially approved behaviors, and the level of frustration (Rosenthal, 1955; Cattell and Scheier, 1958). However, at the present time, future studies are required to adequately address these questions regarding experimental dives of exceptional depth and duration of confinement.

All of these data suggest that studies investigating personality traits, as possible predictors for the development of anxiety, could constitute a valuable line of investigation during deep dives of exceptional depth and duration of confinement. However, because the ASQ is not a very

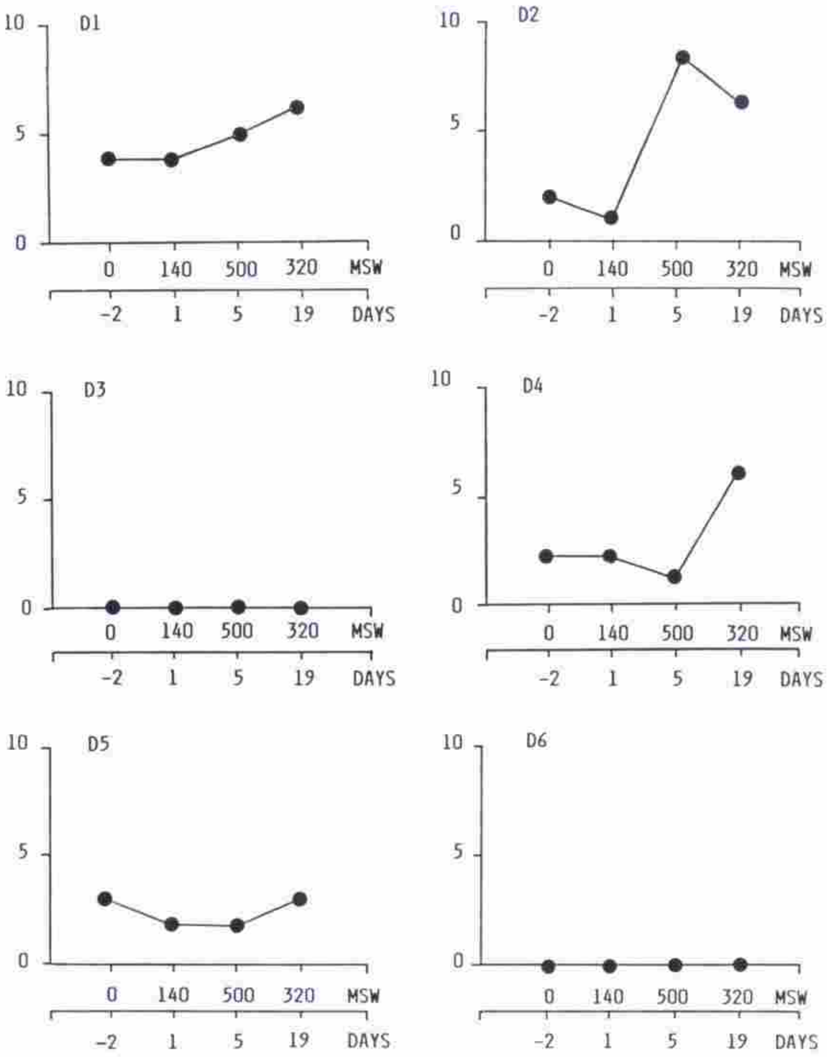

Figure 2: Changes in anxiety standard scores in the six subjects at surface (day −2), 140 (day 1) and 500 meters of sea water (msw; day 5) on compression, and 320 msw (day 19) on decompression.

sensitive scale for the personality factor investigation (Krug et al., 1976), such studies will require the use of a specific personality factor questionnaire. Interestingly, such research could be further coupled to biological studies of peripheral adrenergic and noradrenergic function insofar as perturbations in these systems have been linked to anxiogenic responses (Boulenger and Uhde, 1982) in humans.

In conclusion, although some narcosis (Abraini et al., 1994) and limited anxiety was clearly detectable during this experimental open-sea dive all of the divers were able to work successfully in the open sea environment during a total time of 27 h in six excursions. Therefore, since hydrogen pressure seems to have neither metabolic toxic (Brauer and Dutcher, 1987; Miller, 1987) nor anxiogenic effects per se, as demonstrated in the present study, hydrogenated diving breathing mixtures seem therefore to constitute a useful tool for deep diving. Nevertheless, as previously reported for the individual susceptibility to the high pressure neurological syndrome, the present study further underscores the relevance of psychological investigations for the selection of divers participation in dives of exceptional depth and duration of confinement.

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