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Control of HPNS in humans during rapid compression with trimix to 650 m (2132 ft)

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Bennett PB, Coggin R, Roby J. Control of HPNS in humans during rapid compression with trimix to 650 m (2132 ft). Undersea Biomed Res 1981; 8(2):85–100.—In 1978 a series of deep trimix ($He-N_2-O_2$) dives was initiated to establish the relationship between a given nitrogen percentage and the rate of compression required to prevent the high pressure nervous syndrome (HPNS) at 460 m (1509 ft) and to determine the effects of inspired gas density, hydrostatic pressure, and narcosis on various circulatory and respiratory parameters, including the presence of dyspnea. In 1979, three human subjects were compressed to 460 m in 12 h 20 min with 5% N_2 in $He-O_2$. This resulted in nausea, vomiting, fatigue, tremors, and other signs and symptoms of HPNS that were especially prominent on arrival at that depth but had much improved by Day 2. In March 1980 the same profile was repeated but with 10% N_2 in $He-O_2$. The divers arrived at 460 m with virtually no symptoms of HPNS, but the psychometric performance, as for Atlantis I, still was decreased by some 40% on Day 1 and recovered to some 15% by Day 2. After 5–6 days at 460 m further extension of the dive to 650 m (2132 ft) with a 7.7% N_2 mixture for 24 h showed similar control of symptoms of HPNS, although inspiratory resting dyspnea was present in one subject. The results are discussed in relation to the interactions of nitrogen percentage and rate of compression.

HPNS	helium
trimix	nitrogen
tremor	pressure
compression rate	performance

In 1965 men were compressed to 183 m (600 ft) for 4 h and 244 m (800 ft) for 2 h at rates of 27.7 m/min (91 ft/min) to produce the first report of signs and symptoms, initially attributed to the helium but later to the pressure itself, that were called the high pressure nervous syndrome, or HPNS (1–4). It is now well recognized that rapid compression to depths greater than 152 m (500 ft) induces HPNS with dizziness, nausea, vomiting, postural and intention tremors, fatigue and somnolence, myoclonic jerking, stomach cramping, increased slow-wave and decreased fast-wave activities of the EEG, decrements in intellectual and psychomotor performance, poor sleep with nightmares, and, in animals, convulsions (5–8). The faster the rate of compression and the deeper the depth, the more severe are the signs and symptoms, so that human exposures between 457 m (1500 ft) and 610 m (2001 ft), even with compressions of 3 to 10 days, have often resulted in incapacitating HPNS (9, 10).

Various methods therefore have been used to ameliorate the signs and symptoms of HPNS (11): e.g., selection of less-sensitive divers, slow exponential compression with stages for adaptation, use of excursions from a shallow saturation exposure, adaptation with time at depth, and the use of narcotics to antagonize the effects of HPNS.

In 1973 the F.G. Hall Laboratory initiated the first studies in human subjects on the value of adding the narcotic nitrogen to helium-oxygen (trimix) to prevent signs and symptoms of the HPNS (12) in rapid compressions—to 219.5 m (720 ft) with N_2 at 25%, and to 305 m (1000 ft) with N_2 at 18%. Although HPNS was controlled, nitrogen narcosis occurred. A theoretical model therefore was generated to predict the calculation of the percentage of a narcotic gas adequate to control HPNS (13). For nitrogen the prediction was 10%. Subsequent study in 1974 of the use of 10% nitrogen in heliox (called 10% trimix) in 33 min of compression to 305 m (1000 ft) confirmed its efficacy in suppressing the HPNS (14). In 1975 French workers carried out a four-dive study to 300 m (984 ft) called *CORAZ* (15). These compared the effects of 4-h compressions to 300 m with a heliox control and addition of 4.5%, 4.5%, or 9% nitrogen but utilized a slower 4-h compression and found that the heliox was preferable to the trimix because of the presence of undue euphoria and lassitude with associated EEG changes.

It may be asked whether the slower compression rate of the French study, which would produce less HPNS, was the reason for the difference in these results. Accordingly, in 1979 a series of deep trimix dives were initiated at the F.G. Hall Laboratory. There were two primary objectives of this series, which we named *Atlantis:* first, to establish the relationship between a given nitrogen percentage and the rate of compression required to prevent HPNS; and second, to determine the effects of inspired gas density, hydrostatic pressure, and narcosis on various respiratory and circulatory parameters, such as the frequently reported dyspnea (16).

The first dives (Atlantis I and II) were planned to evaluate and compare the efficacy of either of two nitrogen percentages of content, 5% and 10%, in trimix, with the same compression time of 12 h 20 min, to 460 m (1509 ft), using so far as possible the same subjects.

METHODS

Atlantis I

Three volunteer subjects (Table 1)—a physician's assistant, a commercial diver, and a medical student (DS, LW, WB), none of whom were specially selected—were compressed according to the profile shown in Fig. 1, with a trimix of 5% nitrogen in heliox throughout and an oxygen partial pressure of 0.5 atm, in a total time of 12 h 20 min, with 4 days at maximum depth.

TABLE 1

SUBJECTS IN ATLANTIS I AND ATLANTIS II DIVES

Subject	Age, yr	Height, cm	Weight, kg	VC, liter BTPS	MVV_{15}, liter/min BTPS	$\dot{V}O_{2\,max}$, liter/min STPD	Atlantis Dive No.
WB	25	183	71	6.23	253	3.10	I, II
SP	24	185	87	7.36	244	3.14	II
DS	40	175	79	4.87	195	3.60	I, II
LW	27	173	77	5.20	230	2.95	I

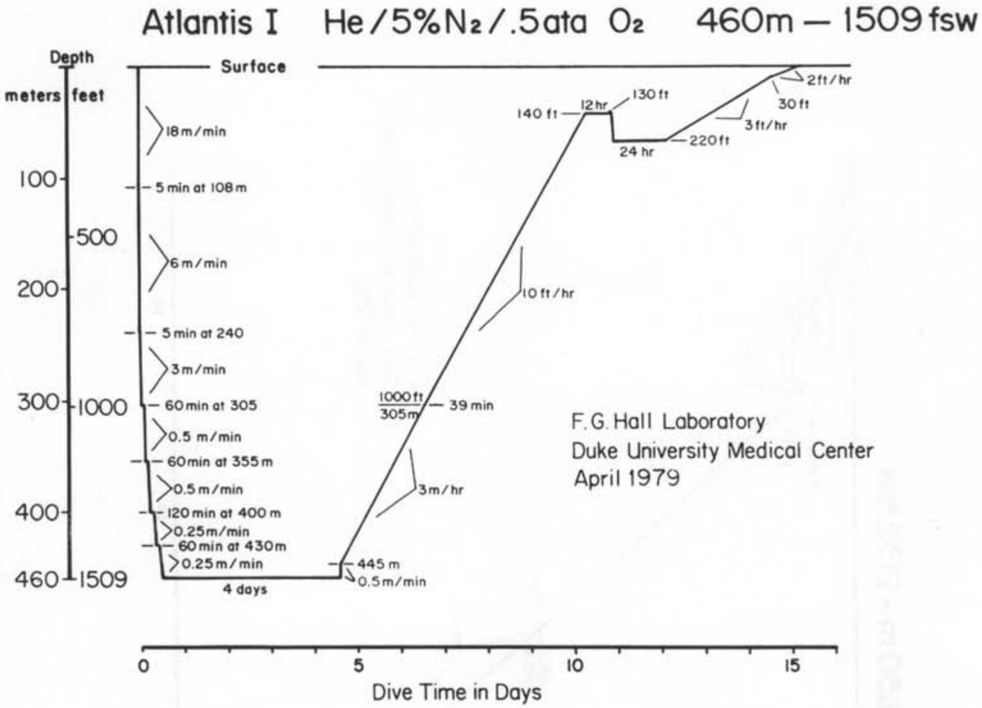

Fig. 1. Dive profile for Atlantis I.

Compression was made with premixed gas containing 5% nitrogen in heliox rather than starting with air and merely adding helium, as in previous trimix dives at this laboratory. This was because of the important findings of Rostain and co-workers (15) with the *Papio papio* monkey, which showed that the best method of preventing HPNS in a trimix dive (N_2 = 6.5%) to 1000 m (3282 ft) was to inject nitrogen seven times during compression, every 100 m (328 ft) from 300 m (984 ft), rather than at the start of end of compression.

Atlantis II

The profile for Atlantis II to 460 m (1509 ft) was the same as for Atlantis I except that a trimix of 10% nitrogen in heliox was used (Fig. 2). On extension of the depth to 650 m (2132 ft) the nitrogen percentage was allowed to fall to 7.7% by compressing with pure helium. This was a precaution against undue respiratory problems due to the increased density of the breathing mixture or the presence of excessive nitrogen narcosis in this first exposure with trimix to this depth. One subject, however, did breathe 10% nitrogen in heliox for 15 min without difficulty. Two of the subjects (DS, WB) were the same (Table 1) as for Atlantis I; the new subject (SP) was a commercial diver.

Content of performance tests

A performance test battery, with a duration of 1 h, was given to the three divers at regular intervals throughout the dive. These were initiated 4 weeks prior to the dive to prevent, so far as possible, learning interactions. Thus each subject carried out at least 26 test batteries prior to the dive itself.

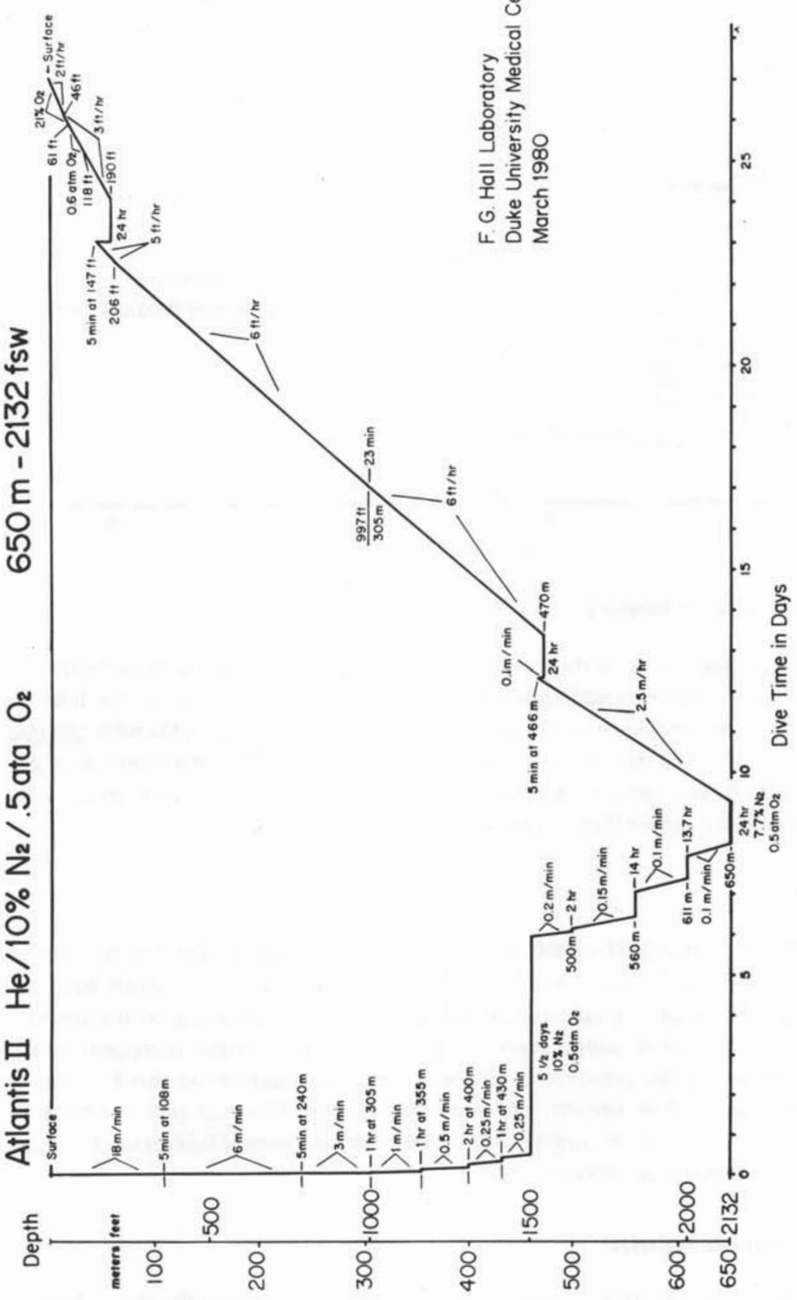

Fig. 2. Dive profile for Atlantis II.

The test battery consisted of the electroencephalogram; measurements of intellectual and psychomotor capacities and postural tremor; and questionnaires about physical sensation, mood, sleep quality, and presence of dreams; the divers kept daily logbooks of events. The tests were designed from those used in previous deep diving studies (11, 13, 17) so as to allow comparison with previous data and with that of laboratories elsewhere.

Questionnaires

Dive questionnaire. The dive questionnaire included questions relating to presence of signs and symptoms of HPNS, breathing, and sleeping effectiveness.

Mood questionnaire. Subjects were asked to rate on a 1 to 10 basis such factors as alertness, coordination, mental state, competence, strength, attention, happiness.

Tests of cognitive function, short-term memory, and intellectual function

AB sentence. The subjects worked through sheets of 64 statements per sheet, saying whether each statement was true or false. Each statement referred to the position of letters A and B and was followed by either AB or BA; the subjects compared the statement with the order and ticked either true or false: e.g., B follows A-AB. True ✓ False ___

Digit span. The subjects heard 8 digits and were required to write them down within 5 s after their presentation. Thirty digit strings were presented for a total test time of 5 min.

Number similarities. The subjects were presented with 40 sets of paired numbers and were given 1 min to mark the nonidentical pairs:

670824317 X 690284317

724767 ✓ 724767

Stroop color and control test. The duration of each color task was 1 min. In the control condition the five color names—green, red, blue, brown, and yellow (all written in black)—were randomly mixed in a row. One of the color names appeared before the row, and the task was to cross out the color name in that row. There were 34 test rows per sheet.

In the color test the five color names (written randomly in the five colors but not in their own colors) were randomly mixed in a row. One of the color names appeared before that row (not written in its own color) and the task was to cross out the particular color (irrespective of its color name) that represented the color name (irrespective of the ink color) of the initial word.

Arithmetic test. The subjects were required to add columns of 5 two-digit numbers. Sixty problems were presented in 5 min.

Psychomotor tests

Tremor. Postural tremor was measured over 1 min with a Grass SPA transducer attached with a rubber band to the middle finger of a subject, and the output was displayed on a Grass electroencephalogram. The recordings were made when the subject was sitting with the hand outstretched and the elbow supported.

Ball bearing test. The subject was required to pick up 6-mm steel ball bearings, using forceps with rounded tips, and put them into a vertical tube with a 7-mm inside diameter. The score was the number of balls in the tube in 1 min.

Purdue pegboard. The diver was expected to use his hands to place a small peg in sequence in each hole in the board and place a washer, a spacer, and another washer over the peg. The score was the number of individual pieces assembled in 1 min.

The Bennett hand-tool test. The subject was presented with two vertical plates with holes in them, the holes of one plate being filled with three sizes of bolts and screws and their appropriate washers and nuts. The time required to loosen the bolts and screws with wrenches and screwdrivers, remove them from one plate, replace them in a mirror-image position on the other plate, and retighten them with the tools was recorded as the score.

Neurophysiological tests

Electroencephalogram. Needle electrodes were attached to the vertex and occipital area for monopolar recordings with a ground to the ear. Measurements were made on a Brush polygraph with on-line frequency analysis by a Nihon Kohden EEG frequency analyzer MAF 5 in the activity bands delta (2–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta 1 (13–20 Hz), and beta 2 (20–30 Hz).

Administration of performance test

The test order was in a fixed pattern each time the tests were presented to the three subjects, who sat in fixed positions around a card table inside the 8-ft-diameter pressure chamber, and the tests were presented so far as possible at the same time of day. One subject began with the ball bearing test, another with the Purdue pegboard, and the third with an accelerometer attached to his finger. After a 1-min test period the equipment was passed around the table; then followed the written tests, which all subjects did together. Finally, while the hand-tool test was being conducted, one of the other subjects secured EEG electrodes to his colleague. After EEG measurements the subjects changed roles until all tests were completed.

Four sets of scores, from the 3 days before the dive and the morning of the dive immediately before compression, were averaged to obtain a mean score on each test for each subject. The graphs of performance during the dives were plotted as the percentage change from this mean score vs. time.

RESULTS

Atlantis I

During the latter stages of compression and immediately on arrival the divers experienced HPNS with nausea, fatigue, somnolence, and lapses of consciousness (microsleep). One subject vomited after eating his lunch. The mood questionnaires showed increased amounts of negative factors such as incompetent behavior and feelings of being troubled, depressed, tense, excited, drowsy, lethargic, and clumsy. Mood improved considerably by Day 2, although the subjects indicated that continuing lethargy and tenseness were present throughout the time at maximum depth. Sleep quality was poor, with vivid dreams and nightmares.

During and immediately after compression on Day 1 of the dive, the mean intellectual performance tests of the three subjects (Fig. 3) indicated decrements that varied from 20% to 50% depending on the test. By Day 2 at 460 m (1509 ft) the results showed considerable improvement, with a decrement of from 10% to 25%. There was some further improvement over the remaining 2 days at maximum depth, but the real improvement did not occur until 341 m (1118 ft) during the decompression; by 300 m (984 ft) the test results had returned to normal values. Sometimes this was to higher than normal values in spite of 26 predive tests given over 4 weeks to help overcome the effects of practice.

Postural tremor was absent, but intention tremor was marked; this condition caused some difficulty with arterial cannulation, several attempts being necessary in one subject before successful catheterization. However, this was completed satisfactorily in all three subjects. The psychomotor tests were less adversely affected than the intellectual tests but showed a similar biphasic depression of ability, especially in the hand-tool test (Fig. 4).

The mean EEG results showed an increase in all frequencies on Day 1 with delta and theta activities (Fig. 5) reaching peak increases over predive controls of +85% and +60%, respectively, and alpha and beta frequencies (Fig. 6) to +10% and +30%. By Day 2 the alpha and beta frequencies had fallen to between −10% and −30% below normal, but the delta and theta activities remained +20% above normal.

Although the divers were able to function very well after Day 2 of this especially fast rate of compression, the performance tests continued to show some decrement (Figs. 3 and 4). This result seemed mainly due to the divers working slower than previously, for all tests were

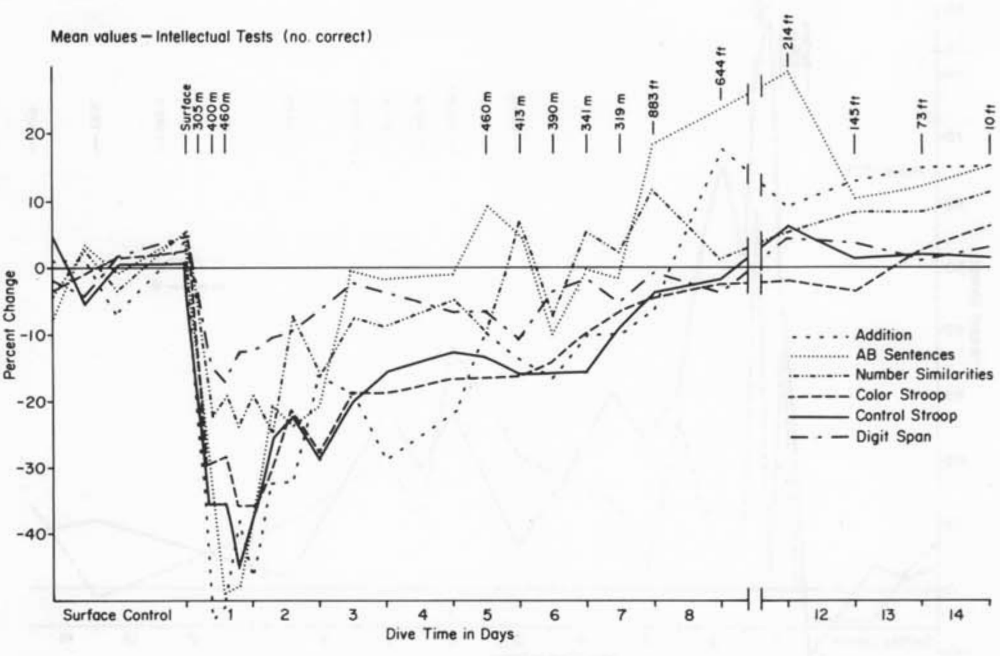

Fig. 3. Mean values of three subjects' intellectual performance tests (numbers correct) during the Atlantis I exposure to 460 m (1509 ft) using 5% nitrogen in helium-oxygen and a compression time of 12 h 20 min. Initial decrement on Day 1 is a function of rate of compression and hydrostatic pressure. From Day 2 the effects are more solely due to hydrostatic pressure.

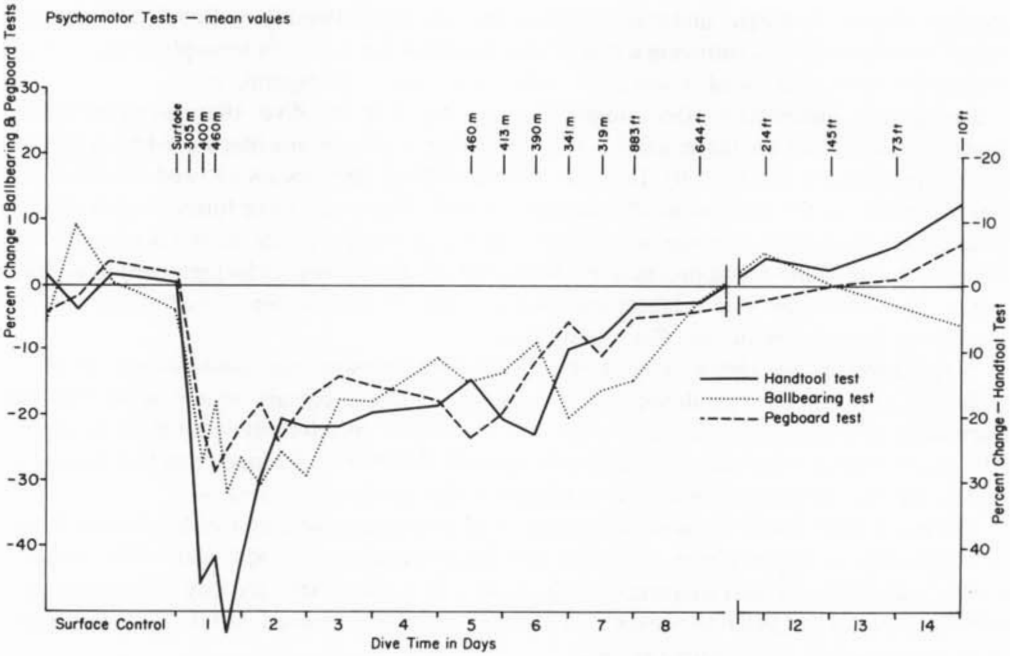

Fig. 4. Mean values of three subjects' psychomotor performance tests during Atlantis I exposure to 460 m (1509 ft) using 5% nitrogen in helium-oxygen and a compression time of 12 h 20 min.

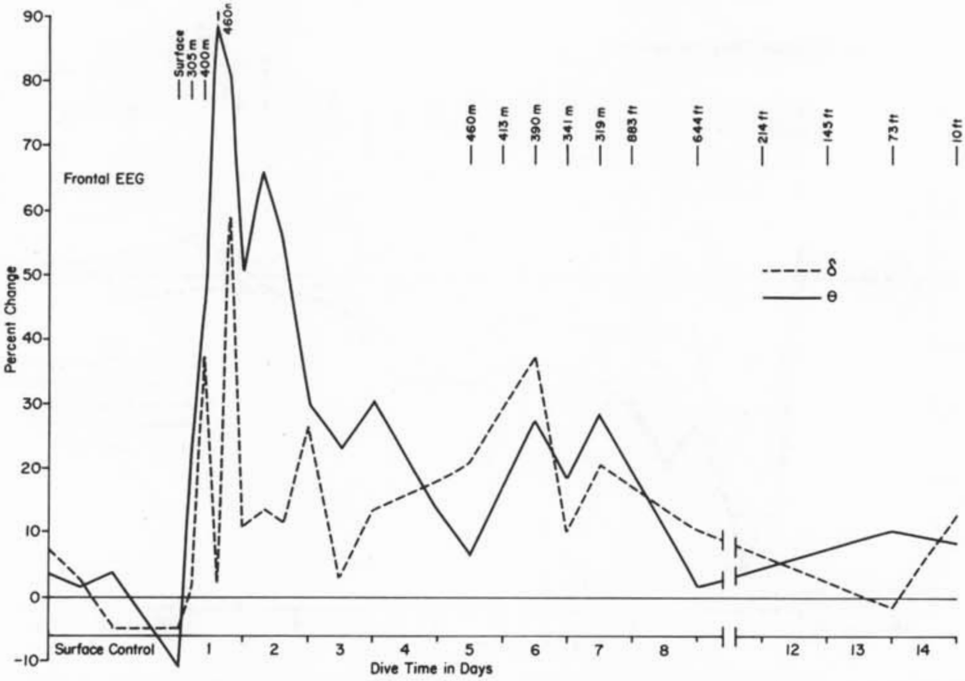

Fig. 5. Mean theta (4–8 Hz) and delta (0–4 Hz) activity of the electroencephalogram of the three subjects for Atlantis I. Compression on Day 1 to 460 m (1509 ft) in 12 h 20 min induced an average 90% increase in theta and somewhat less for delta, with recovery to lower values after compression.

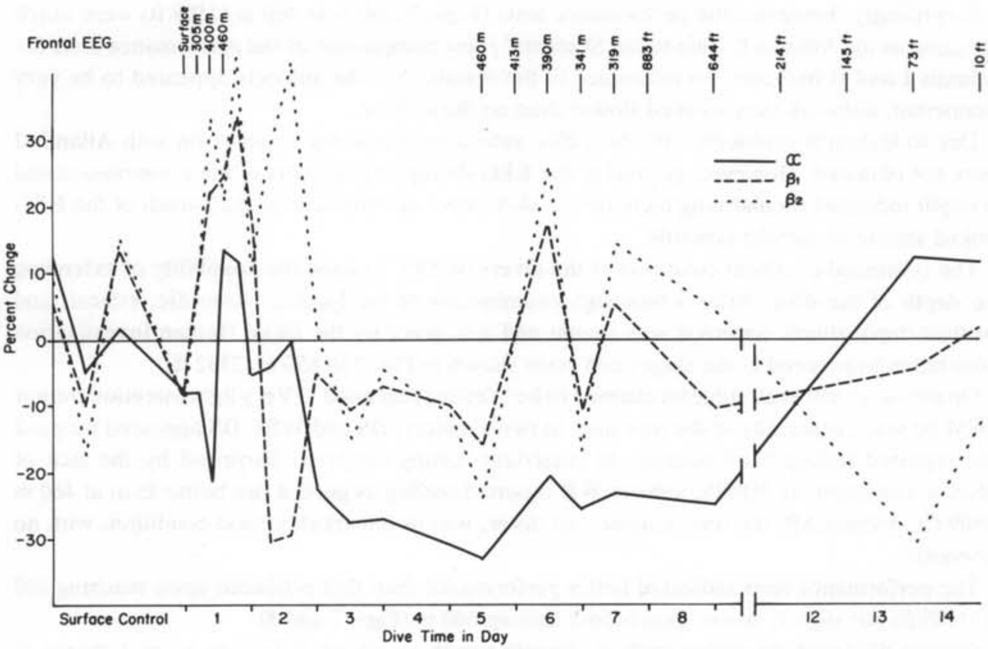

Fig. 6. Mean EEG alpha (8–13 Hz), beta 1 (13–20 Hz), and beta 2 (20–30 Hz) activity of the three subjects in Atlantis I. Conditions as for Fig. 5. Note increase during compression followed by decrease below normal for these activities.

completed satisfactorily, including the very complex pulmonary function measurements (15). After the first day the divers ate well and did not experience the weight loss reported in a number of deep helium dives (18).

Decompression was designed for 7 days using 0.5 ATA oxygen. However, at 42.7 m (140 ft) decompression sickness occurred in the subjects in the form of knee pains. Oxygen breathing was augmented and recompression was then made to 67 m (220 ft) for a 24-h stage at this depth prior to continuing decompression at 0.6 ATA oxygen at a rate of 3 ft/h to the surface.

Atlantis II

By contrast with the results of Atlantis I the three divers arrived at 460 m in fine condition. Compared with the marked negative changes seen in Atlantis I, the mood indicators showed little variation from normal daily range, with little or no indication of drowsiness, lethargy, tenseness, or feelings of being excited, depressed, feeble, clumsy, or troubled. The signs and symptoms questionnaires reported "slight difficulty with breathing" in one case and very minor dizziness and lightheadedness in two subjects during compression at around 305 m (1000 ft) only. By their own admission, at 460 m (1509 ft) all the subjects were feeling considerably better than during Atlantis I. The 10% nitrogen had clearly not only suppressed the postural tremor but also prevented intention tremor, nausea, vomiting, somnolence and lapses of consciousness (microsleep), dizziness, and lightheadedness during the compression (12 h 20 min). This was especially noticeable at depths deeper than 400 m (1312 ft). The subjects ate and slept well, with no nightmares and no effect on body weight.

Surprisingly, however, the performance tests (Figs. 7 and 8) at 460 m (1509 ft) were much the same as for Atlantis I. Two-tailed Students' t test comparison of the performance tests for Atlantis I and II indicated no difference in the results. Yet the subjects appeared to be very competent, although they worked slower than on the surface.

Due to technical problems with the EEG, satisfactory data for comparison with Atlantis I were not obtained. However, perusal of the EEG during critical parts of the compression and at depth indicated no alarming increases in slow-wave activity, and indeed much of the EEG looked similar to surface controls.

The continued excellent condition of the divers on Day 5 raised the possibility of extending the depth of the dive. After a thorough examination of the logistic, scientific, ethical, and medical implications, approval was sought and was given by the Duke Human Investigation Committee to proceed at the stages and rates shown in Fig. 2 to 650 m (2132 ft).

On arrival at 650 m all subjects claimed to be "feeling real good." Very light intention tremor could be seen, especially in the morning, in two subjects (DS and WB); DS appeared fatigued and reported feeling tired because of persistent resting dyspnea. Surprised by the lack of adverse symptoms of HPNS, subject WB reported feeling as good if not better than at 460 m (1509 ft). Subject SP, the only commercial diver, was in remarkably good condition, with no problems.

The performance tests indicated better performance than that produced upon reaching 460 m (1509 ft) but slightly worse than before leaving 460 m (Figs. 7 and 8).

Subject SP noted sensations such as obligate mouth breathing, indicating a "real change in gas density," and experienced more feelings of inspiratory dyspnea when relaxing, eating, or sleeping than when exercising at work loads of up to 120 W. WB stated that he became used to the extra work of breathing, and gas density was not function limiting. Conversely, subject DS reported that approaching and at 650 m (2132 ft) the resting dyspnea he experienced was function limiting. Anything that interrupted regular ventilation (chewing gum, eating, talking) produced an alarming inspiratory dyspnea. However, he performed 30 W of work for 6 min on the bicycle ergometer without difficulty.

Normal meals were eaten, although subject DS ate very slowly because of the dyspnea. The subjects slept well, with less dreaming and nightmares than in Atlantis I. Two of the subjects noted an alarming violence in coughing and sneezing, owing to the high gas density (12.3 g/liter).

During the 24-h stay at 650 m (2132 ft) the subjects between them clearly demonstrated that it is possible to lead a normal existence without nausea, dizziness, vomiting, somnolence, weight loss, or undue tremors (Fig. 9) and to carry out complicated tasks requiring fine manual dexterity, such as venepunctures, and do moderately heavy work (120 W/6 min) on a bicycle ergometer without undue distress (16).

During decompression, as early as 600 to 550 m (1968–1804 ft), as the nitrogen percentage was allowed to fall toward the 5% level planned for 460 m (1509 ft) and none by 300 m (984 ft), HPNS started to appear with bizarre dreams, myoclonic jerking, and to a lesser degree intention tremor. This persisted until about 180 m (590 ft).

At 466 m (1529 ft) one of the subjects (SP) reported persistent knee pain, which resolved after recompression to 4 m (13 ft) with a 24-h hold and the provision of extra oxygen breathing (Fig. 2). Additional decompression problems were experienced at 45 m (147 ft) in two of the divers, one of whom was the subject who was affected deeper.

After recompression and oxygen treatment the divers emerged from the pressure chamber 28 days after entering and were passed fit and well. However, all reported for a few days the usual post-dive malaise often seen after long saturation dives; this passed after a few days upon return to normal levels of activity.

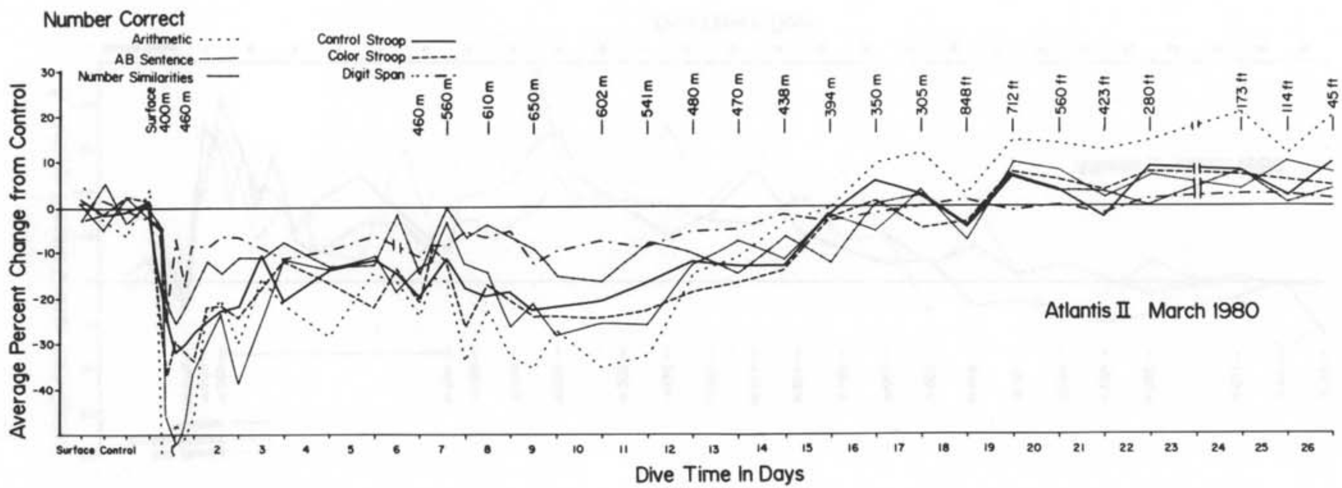

Fig. 7. Mean values of intellectual performance tests (numbers correct) during Atlantis II, which used 10% N_2 in helium-oxygen to 460 m (1509 ft) and 7.7% N_2 to 650 m (2132 ft). Results similar to those of Atlantis I (Fig. 3) are shown. On compression from 460 m to 650 m the performance showed a further decrement but not to levels as low as demonstrated on Day 1 as a result of the 12-h 20-min compression to 460 m.

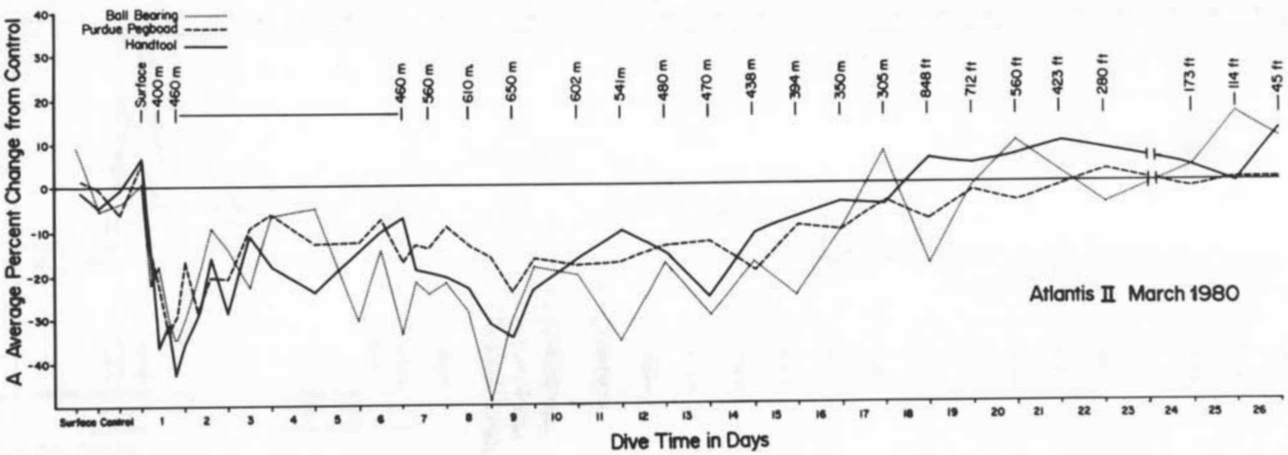

Fig. 8. Mean values of three subjects' psychomotor performance tests during Atlantis II. Conditions as for Fig. 7.

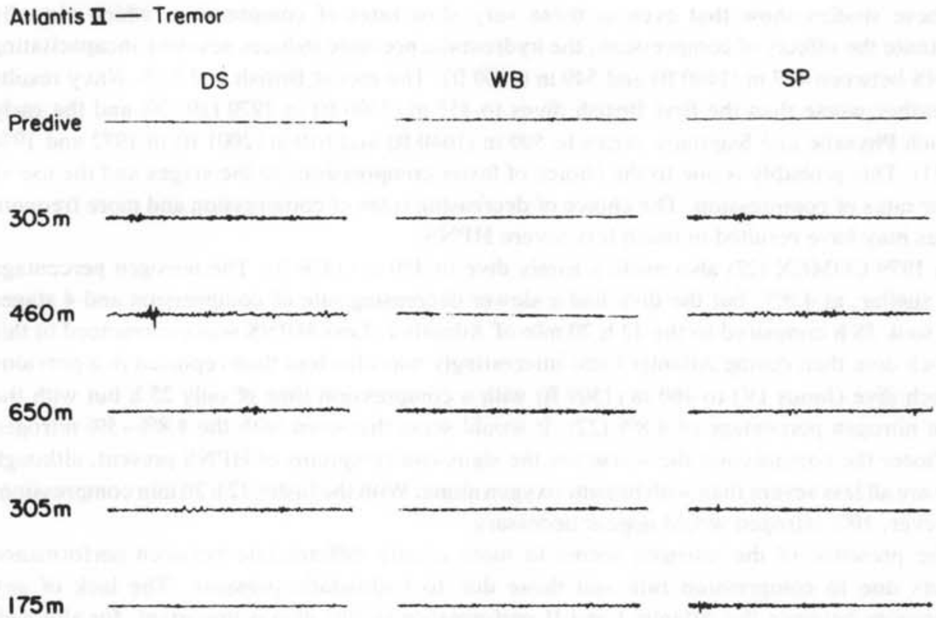

Fig. 9. Postural tremor measurements made from an accelerometer on the right middle finger. Compression to 460 m (1509 ft) in 12 h 20 min and further to 650 m (2132 ft) resulted in very little change.

DISCUSSION

Clearly the use of 5% nitrogen rather than 10% nitrogen for this especially rapid (12 h 20 min) compression to 460 m (1509 ft) is not as effective in prevention of the debilitating signs and symptoms of HPNS. Thus these results are in agreement with the prediction that 10% nitrogen is optimal for control of HPNS (12) and the data are consistent with the earlier studies at Duke (13) conducted with rapid 33-min compressions to 305 m (1000 ft). The compression time is the most rapid compression ever used to such depths and the condition of the subjects far superior compared with other much slower oxygen-helium dives to this depth. For example, in 1979, Admiralty Marine Technology Establishment Physiological Laboratory compressed 2 men to 540 m (1771 ft) with a 3-day 5-h compression (H. V. Hempleman and D. J. Harris 1979, personal communication) using a rate mostly of 5 m/min (16.4 ft/min) with stages every 60 m (170 ft) of either 20 h or 4 h and slower rates of 3 and 1 m/min (9.8 and 3.3 ft/min) deeper than 480 m (1575 ft). Although no overt symptoms were noted at shallower depths—i.e., to 420 m (1377 ft)—at 540 m (1771 ft) there occurred marked nausea, vomiting, tremors, dizziness, and loss of appetite. Intention tremor and epigastric sensations persisted.

The U.S. Navy dive in December 1979 was to 549 m (1800 ft) and had a complex compression profile. First, this involved compression at 6 m/h (20 ft/h) to 198 m (650 ft), where the divers stayed for 8 days. Compression continued at 12.3 m/h (40 ft/h) to 305 m (1000 ft); at 8 m/hr (20 ft/h) subsequently to 488 m (1600 ft); and at 4.5 m/h (15 ft/h) to 549 m (1800 ft). Additional stages were made overnight at 271 m (890 ft), 1 day at 427 m (1400 ft), and 8 h at 463 m (1520 ft). Fatigue, dizziness, nausea, vomiting, aversion to food (with an average 8% weight loss), stomach cramps, diarrhea, myoclonic jerking, and dyspnea were present, and the divers' general condition deteriorated rather than improved with time at depth, but they were able to work at 100 W in connection with respiratory studies (19).

These studies show that even at these very slow rates of compression, which virtually eliminate the effects of compression, the hydrostatic pressure induces severely incapacitating HPNS between 427 m (1400 ft) and 549 m (1800 ft). The recent British and U.S. Navy results are rather worse than the first British dives to 457 m (1500 ft) in 1970 (19, 20) and the early French Physalie and Sagittaire series to 500 m (1640 ft) and 610 m (2001 ft) in 1972 and 1974 (8, 21). This probably is due to the choice of faster compressions to the stages and the use of linear rates of compression. The choice of decreasing rates of compression and more frequent stages may have resulted in much less severe HPNS.

In 1979 COMEX (22) also made a trimix dive to 450 m (1476 ft). The nitrogen percentage was similar, at 4.8%, but the dive had a slower decreasing rate of compression and 4 stages that took 38 h compared to the 12 h 20 min of Atlantis I. Less HPNS was experienced in this French dive than during Atlantis I and interestingly was also less than reported in a previous French dive (Janus IV) to 460 m (1509 ft) with a compression time of only 25 h but with the same nitrogen percentage of 4.8% (22). It would seem that even with the 4.8%–5% nitrogen the faster the compression the worse are the signs and symptoms of HPNS present, although they are all less severe than with helium-oxygen alone. With the faster 12 h 20 min compression, however, 10% nitrogen would appear necessary.

The presence of the nitrogen seems to more clearly differentiate between performance effects due to compression rate and those due to hydrostatic pressure. The lack of any differences between the Atlantis I and II performance results also is important, for although subjectively in Atlantis II the divers appeared in fine condition with little or no HPNS signs and symptoms, their performance test data still showed a decrement, perhaps primarily due to perceptual slowing. The most significant decrements were during compression and immediately on arrival and suggest, in agreement with the earlier discussion, that a compression rate of 12 h 20 min is too fast, even with the use of 10% nitrogen trimix. It may be that a slower compression will prevent much of this performance decrement. In a dive in this laboratory planned for January 1981 and termed *Atlantis III*, 10% nitrogen trimix will be examined under conditions of a compression time twice as long as for Atlantis II.

The present study discussed here has, however, provided further evidence of the value of trimix with 10% nitrogen in the control of debilitating signs and symptoms of HPNS at depths greater than twice those of the original studies at 305 m (1000 ft) in 1974 and under conditions of especially rapid rates of compression.

We are most indebted to the four subjects William Bell, Stephen Porter, Delmer Shelton, and Leonard Whitlock for their courage, determination, and hard work throughout the many months of the Atlantis I and II studies, and to the technical staff of the F.G. Hall Laboratory for their arduous and skilled operation of the chamber facilities throughout these long saturation dives.

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Bennett PB, Coggin R, Roby J. Contrôle de l'SNHP chez les êtres humains lors d'une compression rapide à 650 m (2132 pieds) avec le trimix. Undersea Biomed Res 1981; 8(2):85–100.—En 1978, une série de plongeons profonds trimix (He-N_2-O_2) fut lancée pour établir le rapport entre un pourcentage donné d'azote et le taux de compression nécessaire pour prévenir le syndrome nerveux en haute pression (SNHP) à 460 m et afin de déterminer les effets de densité de gaz inspiré, de pression hydrostatique et de narcose dans différents paramètres circulatoires et respiratoires, y compris la preésence de dyspnée. En 1979, 3 sujets humains furent comprimés à 460 m en 12 et 20 min avec 5% de N_2 dans l'He-O_2. Ceci produisit nausée, vomissements, fatigue, spasmes et d'autres signes et symptomes de l'SNHP qui furent répandus au point d'arriver à cette profondeur mais qui s'étaient améliorés le second jour. En mars 1980 le même profil se répétait mais avec 10% de N_2 dans l'He-O_2. Les plongeurs arrivèrent à 460 m avec presqu' aucun symptome d'SNHP, toutefois, la performance psychométrique, comme il en était le cas avec Atlantis I, était réduit de quelque 40% le premier jour et restitué à environ 15% le deuxième jour. Après cinq ou six jours à 460 m un prolongement de la profondeur jusqu'à 650 m avec un mélange de 7,7% de N_2 pendant 24 h démontra un contrôle semblable des symptomes de SNHP bien que la dyspnée inspiratoire au repos apparut chez un sujet. Les résultats sont commentés enfonction des phénomènes d'interaction du pourcentage d'azote et du taux de compression.

SNHP hélium
trimix azote
spasme pression
taux de compression performance

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