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DESCRIPTION OF THE NASA HYPOBARIC DECOMPRESSION SICKNESS DATABASE (1982 – 1998)

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ABSTRACT

The availability of high-speed computers, data analysis software, and internet communication are compelling reasons to describe and make available computer databases from many disciplines. Methods: Human research using hypobaric chambers to understand and then prevent decompression sickness (DCS) during space walks has been conducted at the Johnson Space Center (JSC) from 1982 to 1998. The data are archived in the NASA Hypobaric Decompression Sickness Database, within an Access 2003 Relational Database. Results: There are 548 records from 237 individuals that participated in 31 unique tests. Each record includes physical characteristics, the denitrogenation procedure that was tested, and the outcome of the test, such as the report of a DCS symptom and the intensity of venous gas emboli (VGE) detected with an ultrasound Doppler bubble detector as they travel in the venous blood along the pulmonary artery on the way to the lungs. We documented 84 cases of DCS and 226 cases where VGE were detected. The test altitudes were 10.2, 10.1, 6.5, 6.0, and 4.3 pounds per square inch absolute (psia). 346 records are from tests conducted at 4.3 psia, the operating pressure of the current U.S. space suit. 169 records evaluate the Staged 10.2 psia Decompression Protocol used by the Space Shuttle Program. The mean exposure time at altitude was 242.3 minutes (SD = 80.6), with a range from 120 to 360 minutes. Among our test subjects, 96 records of exposures are females. The mean age of all test subjects was 31.8 years (SD = 7.17), with a range from 20 to 54 years. Discussion: These data combined with other published databases and evaluated with metaanalysis techniques would extend our understanding about DCS. A better understanding about the cause and prevention of DCS would benefit astronauts, aviators, and divers.

INTRODUCTION

- In 1982, NASA started its decompression sickness research with BENDS I to provide a safe and efficient prebreathe for shuttle Extravehicular Activities (EVAs). At that time, all study data were kept in the form of logbooks and hardcopy spreadsheets, from which analysis and results were derived.
- In 1985, the then head of the JSC Environmental Physiology Laboratory (EPL), Dr. John Gilbert, used the lab's first computer and started digitizing BENDS data into RBASE, a relational database software package. This allowed the entry of test subject and study data into the original tabular format that still serves as the backbone of the current database today.
- In 1989, Dr. Vasantha Kumar decided that his data, and all the rest of the lab's data, would be better served in MS Access and started converting it all into that format.
- In the timeframe of 1989-1994, the database became 'confused' in both data integrity and structure due to the many people inputting data.
- Two EPL hires in the persons of Ms. Keena Acock (1995) and Dr. Karin Loftin (1996) provided the EPL with new data entry expertise and accuracy control and rectified many of the accumulated errors.
- Using original source data, the current database manager, Mr. James Wessel, continues to correct errors and is in the process of uniting the NASA Hypobaric Decompression Sickness Database and the NASA Prebreathe Reduction Protocol database into a single entity for improved data mining and future analysis.

METHODS

- The NASA Decompression Sickness Database is in a MS Access 2003 format and currently consists of 28 tables and 868,791 cells.
- There were 548 viable test exposures from 238 test subjects, in 11 major studies, under 31 unique testing procedures.
- For details about each of the major tests, the reader is referred to the notebook in the immediate vicinity of this poster, labeled "Testing Regimes".
- The studies below were tested with ambulatory subjects, had long resting prebreathes or overnight stays at 10.2 psia and utilized 26.5% oxygen:
  - Evaluation of 3.5 - 4.0 hour resting prebreathe (BENDS 1-2, 4, 6)
  - 10.2 psia Staged Decompression Protocol (BENDS 3, 4, 5, 9)
  - Evaluation of a 6.5 psia EVA suit (BENDS 6)
  - Evaluation of high exercise rate during EVA (BENDS 7)
  - Evaluation of pre-EVA exercise and risk of DCS and VGE (BENDS 8)
  - Evaluation of Flying after Diving (BENDS 10)
- The studies below were specifically done to understand the benefits of adynamia prior to and during the altitude exposure:
  - Evaluation of adynamia (BENDS 9 and 11)
- JSC standard operating procedures require a modified Air Force Class III Physical, so that data is included in the database.
- Subjects were recruited to approximately match the physical characteristics of the astronaut corps.
- About half the testing data were collected under test termination rules that allowed the test to continue until the ability to perform EVA-simulation exercise was hindered, or the subject wished to terminate the exposure. This was later amended through the Institutional Review Board to a more conservative approach to ensure greater safety for the pool of test subjects.

RESULTS

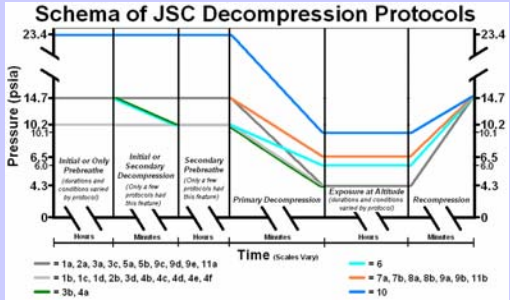
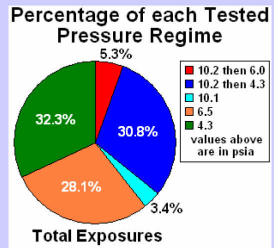


Figure 1 shows the various pressure regimes used throughout the history of DCS research conducted at JSC. Readers are encouraged to follow individual lines from left to right to better understand the 31 conducted testing protocols. Divergence points at the right end of a subsection of grey line illustrate marked differences between protocols with similar prior pressures, while convergence points show a shared feature of multiple protocols.

Figure 2 shows our 548 test exposures broken into 5 major categories. Two of these were evaluations of the 10.2 Staged Decompression protocol with different final decompression endpoints to mimic two potential spacesuit pressures. One pressure regime examined the potential ramifications of flying at 10,000 ft (10.1 psia) after a simulated dive to 20 ft. Another important study was performed on the feasibility of a 6.5 psia space suit. Finally, nearly a third of all exposures had a test pressure of 4.3 psia without an intermittent decompression step to provide additional insight on some of our potential prebreathe protocols.



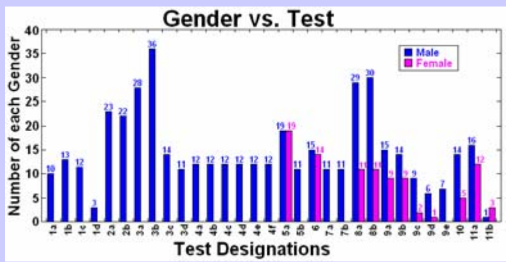


Figure 3 shows that initial DCS research at JSC (1982-84) used male test subjects. The test subject pool was later expanded to include females in 1985. All subsequent testing has attempted to have a ratio of males to females that closely mimics the gender composition of the astronaut corps, while allowing for the difficulties of test subject recruitment.

Figure 4 shows gender by various pressure regimes to illustrate the involvement of female test subjects in almost all the major testing protocols that we have conducted. The lone standout is the earliest staged decompression testing (circa 1982) that lead to the development of the still used 10.2 Staged Decompression for Shuttle based EVAs.

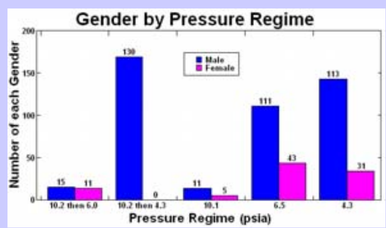
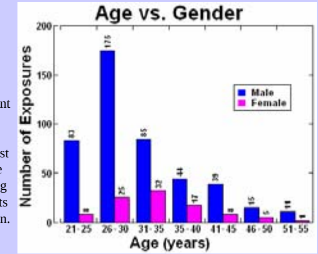


Figure 5 shows the age and gender distributions in 548 exposures. A criterion we used to evaluate our testing is how closely the test subject age matches that of the astronauts. Unfortunately, the overall test subject recruitment over the years has not perfectly mimicked the ageing astronaut corps. The average age of astronauts is about 43 years, while that of our test subjects is about 31 years. The subset of female test subjects is slightly skewed towards matching the mean astronaut age, but the male test subjects are decidedly younger on average, in comparison.



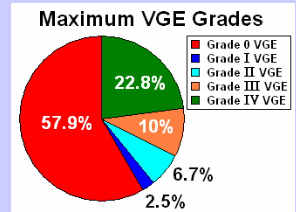
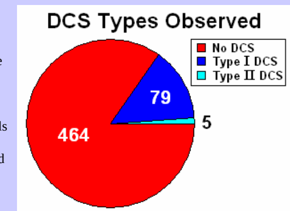


Figure 6 shows the maximum VGE grades assigned during the majority our testing protocols. When VGE are present, they rapidly manifest themselves into the higher classifications of Grades III and IV. Nearly a third of all our possible VGE scores fall into those two combined categories.

Figure 7 shows the number of Type I and Type II DCS cases in our database. We plan our prebreathe protocols to be safe to prevent astronauts from experiencing DCS. As a result, it should not be surprising that 84.7% of the total of all our decompression exposures across all testing protocols resulted in no observed DCS. In comparison, we recorded Type I DCS in 14.4% of the exposures and Type II DCS accounted for only 0.9% all testing.



DISCUSSION

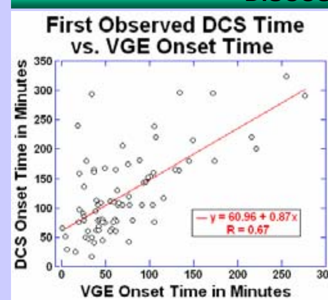


Figure 8 shows that the onset of DCS symptoms often occur later than the onset of VGE detected in the pulmonary artery using a Doppler bubble detector. The graph shows points that are from a subset of subjects where both VGE were detected and DCS symptoms were reported. In general, the presence of VGE in the pulmonary artery are a necessary but not sufficient condition for DCS. VGE first detected later in an altitude exposure correspond closer to the onset of DCS symptoms than VGE first detected earlier in the altitude exposure.

Future Direction of Work: The next major step in the evolution of the NASA Hypobaric Decompression Sickness Database is to merge it with the NASA Prebreathe Reduction Protocol Database into a common format (MS Access). Efforts in this process are already underway. The combination of the two would provide increased data mining opportunities across identical fields for additional analysis. It is hoped that the final merged database will be hosted on a JSC server and that it would be Internet accessible by researchers at other institutions.