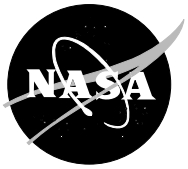
Shuttle-Mir Science Program
Phase 1A Research
Postflight Science Report

March 1998



National Aeronautics
and Space Administration

Lyndon B. Johnson Space Center
Houston, TX

Contents

Introduction

The Shuttle-Mir Science Program, also known as the Phase 1A program, was developed as a result of a joint agreement between the United States and the Russian Federation which initiated a cooperative human space flight program. The program consisted of two long duration missions, Mir 18 and Mir 19, and one Shuttle docking mission, Spacelab-Mir (SL-M) STS-71.

The Mir 18 mission began with the launch of the Soyuz TM21 on March 14, 1995, carrying two Russian cosmonauts, Mission Commander Lieutenant Colonel Vladimir N. Dezhurov and Flight Engineer Gennady M. Strekalov, Ph.D., and U.S. Astronaut, Mission Specialist Norman E. Thagard, M.D. The Soyuz TM21 docked with the Mir on March 16, 1995. After a 116 day stay in space, most of it on the Russian Space Station Mir, the Mir 18 crew landed at Kennedy Space Center on July 7, 1995. The STS-71 crew consisted of Commander Captain Robert L. "Hoot" Gibson, Pilot Lieutenant Colonel Charles J. Precourt, Mission Specialist Ellen S. Baker, M.D., Mission Specialist Gregory J. Harbaugh and Mission Specialist Bonnie J. Dunbar, Ph.D. The SL-M mission also provided return transportation for the Mir 18 crew and transportation for the Mir 19 crew to the Mir.

The Mir 19 mission continued the joint science program and began with the launch of U.S. Space Shuttle Atlantis carrying two Russian cosmonauts, Mission Commander Colonel Anatoly Y. Solovyev and Flight Engineer Nikolai M. Budarin, to the space station Mir. Mir 19 was concluded on September 11, 1995, with the landing of Soyuz TM21 in Russia.

The Shuttle-Mir science program used the U.S. Space Shuttle and the Russian Space Station Mir capabilities to conduct joint research activities in space. Seven research areas encompassing 28 investigations were conducted on Mir and/or the Shuttle. The overall objectives of the Shuttle-Mir missions were to obtain engineering and operational experience in conducting research on an orbital space station; to conduct specific investigations in medical support, life sciences, fundamental biology, microgravity sciences, Earth observations, and life support technology; and to characterize the environment relative to microgravity and life sciences research on Mir to better understand past and future investigations. Included in this report are the final science reports from the investigations performed on Mir 18, STS-71, and/or Mir 19.

Section 2: Cardiovascular and Cardiopulmonary Reports

Studies of Orthostatic Intolerance with the Use of Lower Body Negative Pressure (LBNP)

U.S. Principal Investigator: **JOHN B. CHARLES, Ph.D.,** NASA/Johnson Space Center

Co-Investigators: V. Mikhaylov and J. M. Yelle

Co-Author: K.R. Collier

Technical Assistants: D. Barker, M. Wood and Y. Kobzev

Statistical Analysis: K.K. Bolton

(Mir 18 Final Science Report)

INTRODUCTION

EXPOSURE TO WEIGHTLESSNESS, even for short periods, induces significant changes in the cardiovascular system which are proposed to be secondary to headward fluid shifts, subsequent plasma volume contraction, and ensuing adaptations in cardioregulatory function (Hoffler, 1977; Blomqvist and Stone, 1983; Bungo, 1985; Charles, 1991; Fritsch, 1992, 1993) The resulting cardiovascular state may be inappropriate for orthostasis on Earth's surface, as revealed by tachycardia, blood pressure lability, lightheadedness, visual disturbances and presyncope. These findings mark the condition of postflight orthostatic dysfunction. In the extreme, syncope (fainting) may occur, and the dysfunction thus becomes intolerance. This dysfunction, which has been observed in a small though perhaps significant percentage of crewmembers throughout the Shuttle program, is of particular concern as space flight durations increase, presumably predisposing the astronauts to an even greater risk of orthostatic dysfunction during and after entry and landing (Charles and Lathers, 1991).

The U.S. investigators (Charles and Yelle) have routinely tested the orthostatic function of all Space Shuttle astronauts before and after space flight using a "stand test" in which the astronaut's heart rate and blood pressure are monitored in both the supine and standing postures for 5-10 minutes (Bungo 1985). Documentation of the development of orthostatic dysfunction **during** space flight requires a gravity-independent technique such as lower body decompression, historically referred to as "lower body negative pressure" (LBNP). Inflight LBNP, which may decompress the legs and lower abdomen by 50 mmHg, provides a cardiovascular stress similar to that induced by gravity on Earth by causing blood to pool in the lower body. Brief decompressions are used as gravity-independent tests of orthostatic function (Wolthius, 1974), while longer decompressions have been used as treatments to reverse orthostatic intolerance in bed-rested subjects (Hyatt and West, 1977) and astronauts (Fortney, 1991).

Since the late 1970s, almost all inflight use of LBNP has been directly or indirectly related to the refinement and application of a treatment, or "countermeasure", with only an occasional independent study examining the mechanisms of altered orthostatic tolerance as a result of weightlessness. For example, the current LBNP capability for use on the Space Shuttle was developed for the recently concluded Extended Duration Orbiter Medical Project (EDOMP) investigations of the effectiveness of a proposed countermeasure. However, inflight baseline measurements provided information on the adaptive changes in the mechanisms of orthostatic function that occur normally during weightlessness. Note, that this Mir investigation used LBNP only to determine the time-course and mechanisms of the development of orthostatic dysfunction during 115 days in weightlessness. This work was part of an integrated study of changes in autonomic control of the cardiovascular system which also includes the Shuttle-Mir Science Program (SMSP) experiments, "Studies of Mechanisms Underlying Orthostatic Intolerance Using Ambulatory Monitoring, Baroreflex Testing, and the Valsalva Maneuver" (Experiment 3.1.2) and "Fluid and Electrolyte Homeostasis and Its Regulation" (Experiment 2.1.1). Data collection was also done throughout the routine application of the Russian countermeasure program during the last days of the mission. Specific analysis of this countermeasure and its efficacy focused on comparing responses before and after the treatment. An in-depth comparison of the Russian and NASA LBNP countermeasure was **not** performed.

Objectives

To determine the time-course and mechanisms of the loss of orthostatic tolerance associated with extended weightlessness.

To confirm and extend previous U.S. and Russian research, and provide a standardized, reproducible measure of integrated circulatory control against which other planned specific measurements of autonomic function can be interpreted.

Hypotheses

During the first month in orbit, at each level of LBNP stress, there will be a significant **increase** in heart rate (HR) and diastolic blood pressure (DBP), a significant **decrease** in systolic blood pressure (SBP) and pulse pressure (PP), and **no** significant difference in mean arterial blood pressure (MAP), compared to preflight values.

After the first month in orbit, there will be no further significant change in HR, SBP, DBP, or MAP response to each level of LBNP stress.

There will be **no** significant difference between the HR, SBP, DBP, MAP or PP responses to LBNP of the Mir crew (1995) and the U.S. *Skylab* crews (1973-74) before the application of the standard Russian end-of-mission countermeasures.

During LBNP on the last day in flight (that is, during the last Russian required LBNP treatment session), there will be significantly **smaller** HR response to each level of LBNP stress compared to values measured in the same crewmember in flight before the treatment began.

Immediate postflight LBNP testing will reveal **smaller** HR and BP responses to corresponding levels of LBNP than were found after the 84-day *Skylab* flight, but **larger** HR and BP responses than after Shuttle flights of 14 days or less, indicating that the Russian treatment only partially restores the responses to LBNP to their preflight values.

By 6 weeks after landing, postflight HR, BP, SV, CO and TPR responses to LBNP will be indistinguishable from preflight responses.

Background/History

The first inflight LBNP assessment of orthostatic function was carried out on the Soviet Union's *Salyut 1* Space Station in 1971 (Degtyarev, 1971). Two cosmonauts were tested in flight using an early version of the now standard Chibis pneumatic vacuum suit (Barer, 1975). Since 1975 LBNP testing has been performed on virtually every *Salyut* and Mir mission. In agreement with the U.S. *Skylab* data, testing of the crews of the *Salyut 5* mission indicated that individual responses to inflight LBNP tests were predictive of postflight responses to orthostatic stress (Degtyarev, 1980)

The *Skylab* program (1973-1973) allowed U.S. investigators to use LBNP to determine the time course of the development of orthostatic dysfunction in weightlessness (R.L. Johnson, 1975, 1976, 1977). During all three *Skylab* missions (28-, 59-, and 84-day durations), crewmembers' heart rate (HR) and blood pressure (BP) responses to a standardized graded LBNP stress were determined at approximately 3-4 day intervals.

After a lapse of 16 years, the U.S. again used LBNP during space flight in our investigations on 9 Space Shuttle flights since 1990 (Charles and Fortney, 1993-DSO 478 EDOMP Status Report). Although the primary objective of our work has been to validate an LBNP-based countermeasure, we have also documented the inflight responses to weightlessness earlier than was possible on *Skylab*. Early inflight measurements on the Shuttle were made on flight days (FD) 2-3 and again on FD 5, 6, or 8; on *Skylab*, they were made on FD 4-6. Thus, the Shuttle and *Skylab* data sets together provide information on the continuum of changes from early in flight through the steady-state condition attained after several weeks in weightlessness.

U.S. (Bungo, 1986) and French researchers (Pottier, 1988; Arbeille, 1991, 1994) have used ultrasound echocardiography to investigate the cardiovascular responses to short (7-25 days) space flights in resting astronauts on the Space Shuttle and the Mir. Those results show that HR and total peripheral resistance (TPR) are increased, stroke volume (SV) is decreased, and BP and cardiac output (CO) are almost unchanged compared to preflight supine values. Arbeille has investigations in work on the Mir to look at echocardiographic data during LBNP tests in flight, and U.S. investigators have combined echocardiography with LBNP testing on several Shuttle missions.

METHODS/SCIENCE OPERATIONS

Functional Objectives

FO1. "Ramp" Protocol - LBNP Test

FO2. LBNP Training Protocol - End of Mission (EOM) Countermeasure

Hardware Items

HW1. "Skylab" LBNP Device - NASA PI provided

HW2. Russian Chibis LBNP Device - Russian PI provided

HW3. SD-designed Collapsible LBNP Device (inflight) - NASA provided

HW4. AERIS Echocardiography device - NASA provided

HW5. Biosound Echocardiography device - PI provided

HW6. Portapres and Finapres Continuous Blood Pressure Device (CBPD) - NASA and PI provided

HW7. Data Acquisition System (DAS) - NASA provided

HW8. Russian "Gamma" ECG and BP system - Russian PI provided

HW9. ECG monitors, strip chart recorders, and test equipment - PI provided

HW10. Automatic Blood Pressure Monitor - PI provided

HW11. TEAC data recorders - PI provided

HW12. Chibis Low Pressure Transducer - NASA provided

Method/Protocol

This investigation used periodic repetitions of the standard U.S. Shuttle LBNP protocol to determine the time-course and mechanisms of the changes in the autonomic nervous control of the cardiovascular system associated with extended exposure to a weightless environment. Three subjects first underwent preflight presyncope-limited (PSL) tests (Fortney, 1991) to determine their maximum LBNP tolerance. Baseline, inflight, and postflight data were collected using the "response" or **Ramp** LBNP test. This test consists of 10 minutes of data collection at baseline or control (0 mmHg), followed immediately by stepwise decreases in pressure of 10 mmHg increments down to -50 mmHg. Each stage was 5 minutes. The test was completed with a 5 minute recovery period after returning to 0 mmHg.

ECG and continuous blood pressure was collected throughout the test, as well as arterial BP from a manual arm cuff once per minute. Ultrasonographic measurements of cardiac left ventricular dimensions (2-D and M-mode) and blood flow velocity (pulsed-wave Doppler) through the mitral and aortic valves were made during the pre-test resting control period; measurements of aortic blood flow velocity (stroke volume or SV) continued throughout the LBNP decompression and recovery periods. From these ultrasound measurements, cardiac output (CO=SV*HR) and total peripheral resistance (mean arterial pressure/CO) were calculated.

These Ramp tests were performed on three occasions preflight, on several occasions in flight on both Mir and the Shuttle (see sessions table) and at least once postflight. HR and BP data was also acquired during LBNP treatment sessions on each of the last two full days in orbit before Shuttle landing.

RESULTS

List of Pre-, In-, and Postflight Anomalies

Preflight Anomalies

There were no preflight anomalies.

Inflight Anomalies

There was one minor anomaly during LBNP operations on the Mir. The continuous blood pressure device (CBPD) filled its memory buffer, causing an error message to be displayed. 18-CR called this to our attention and was instructed to ignore this message as it did not affect data collection and science results.

There was one anomaly during LBNP operations on the Shuttle. The LBNP "countermeasure" protocol programmed into the LBNP Controller was different from that printed on the cue card in the PFDF. Crewmembers were instructed to follow the protocol as programmed as this did not affect science.

Postflight Anomalies

There were no hardware related anomalies during postflight testing.

Completeness/Quality of Data

The quality of the data which we have is fair. However, we lost ALL "Gamma" ECG and BP data from LBNP sessions conducted on the Mir station. Evidently, cabling configuration between the Russian hardware and the U.S. recording device was not correct. We believe this was due to misinformation regarding the setup of a "handshaking" device designed to route signals from the "Gamma" system to the TEAC data recorder. Further investigation is necessary to prevent this problem in future experiments. We do, however, have Chibis decompression pressure and Portapres (CBPD) continuous blood pressure data for the LBNP sessions conducted on Mir.

Data collection on STS-71 was compromised due to the inability of one subject to participate in inflight LBNP testing.

Completeness of preflight and postflight data was severely compromised due to inconsistent participation in the LBNP protocols by the Russian cosmonauts. Several reasons were given at the time, but we will not speculate further on this matter. The complete assessment of many hypotheses is hampered by the protocol deviations.

Tables, Graphs, and Figures Index

Table 1. Data Collection Sessions/Functional Objectives

Figure 1. Averaged Heart Rate data from preflight and inflight LBNP "ramp" tests on Shuttle (<15 days), Skylab (28-84 days) and Mir (110 days) crewmembers. It is apparent that all three groups are similar, both preflight and in flight at their respective test times.

Figure 2. Preflight, inflight, and postflight comparisons of Systolic, Diastolic, and Mean Arterial

Blood Pressure, Heart Rate, Stroke Volume, and Total Peripheral Resistance at maximum decompression (-50 mmHg). There is a significant increase in Heart Rate from preflight to in flight (p=0.04) as was expected for the three Mir crewmembers. There were no significant differences in any other parameters.

Figure 3. Measure of tolerance - Systolic, Diastolic, and Mean Arterial Blood Pressure, Heart Rate, Stroke Volume, and Total Peripheral Resistance are presented as the % change from 0-50 mmHg (control to maximum decompression). This figure illustrates the delta from baseline, thus factoring in the different endpoints for each crewmember and presenting the result as a group average. The change in Stroke Volume was significantly greater in flight and postflight compared to preflight (p=0.02). No other parameters exhibited a significant change, in part due to the large individual variability and small sample size. In fact, the low statistical power for all of these comparisons should be considered when drawing any conclusions from these data.

DISCUSSION

Status of Data Analysis

All data has been obtained by the U.S. PI team with the exception of telemetered data, from the two cosmonauts, collected during inflight LBNP on the Mir. We attempted to obtain this data from our Russian counterparts and were rebuffed as it is considered medically sensitive. In retrospect, any such telemetered data is of little value for our purposes due to the frequent interruptions of radio communication.

Research Findings

This investigation set out to test six hypotheses (stated in section I.B. previously) and to gather additional information regarding cardiovascular responses to lower body negative pressure after long-duration space flight. This task was made especially difficult due to several factors beyond the principal investigator's control, including: preflight and postflight data collection scheduling difficulties, loss of inflight data due to faulty configuration of Russian hardware, and inconsistent participation in and execution of protocols which were made necessary by health concerns of the Russian medical authorities for the Russian crewmembers. However, analysis of the data obtained allows us to make the following statements about each hypothesis:

1. Heart rate response to LBNP was significantly increased (p=0.04) in flight compared to preflight. Stroke volume exhibited a larger decrease (p=0.02) from baseline during inflight and postflight testing compared to preflight (although the necessary hardware for making this measurement was demanifested from the Mir, we were able to obtain this data during inflight testing on the Shuttle, and thus make comparisons based on that data); however, all other cardiovascular parameters measured showed no statistically significant changes. [See figures 2 and 3]

2. Hypothesis #2 was unable to be fully tested due to loss of a major portion of data collected on Mir. However, the data that we do have appears to indicate that LBNP responses were altered as anticipated.

3. The data indicate that there were no significant differences in the LBNP heart rate responses of the Mir crew compared to those of the *Skylab* crews [figure 1]. Blood pressure responses were equally similar.

4. Small sample size and other confounding factors make us unable to determine whether heart rate response on the last day in flight was significantly less (after LBNP treatment, or "countermeasure", sessions took place) compared to sessions earlier in the mission (before treatments).

5. Heart rate and blood pressure responses in the Mir crewmembers to postflight LBNP testing were similar to both *Skylab* and Shuttle data. Small sample size and other factors make the statistical power too low to state whether there are significant differences.

6. Postflight testing was only carried out to 6 weeks on one crewmember. This one crewmember's LBNP response was similar to preflight at this test time. However, the other crewmembers were unavailable for testing at R+45, thus we are unable to fully address hypothesis #6 (the original research proposal called out for testing on all crewmembers through 6 weeks postflight).

Conclusion

Cardiovascular deconditioning occurs early in flight, and has only partially recovered within 2 weeks postflight. Data was collected on only one subject at R+45 days, so the time course of complete recovery cannot be specifically determined for the entire group.

Without a control group, and due to the confounding factors previously stated, we are unable to make any conclusive statements regarding the effectiveness of the Russian LBNP (or any other) countermeasure.

We suggest that future investigations continue to document the problem of cardiovascular deconditioning in order to increase the number of subjects, so that more definitive conclusions can be made. These investigations should include inflight catecholamine determinations, echocardiography measurements, and pre- and postflight integrated stand tests (**including** landing day).

In summary, we must state that a very difficult task was undertaken with this investigation. Despite the data

quality problems we encountered, much was learned from the results we gathered, both scientifically and operationally. Our team of scientists and engineers worked together and overcame many obstacles, solved several engineering problems, conducted successful training sessions, and helped open a new era in the U.S. space program. We are thankful for the opportunity to participate in this phase of the NASA cooperation with the Russian Space Agency.

REFERENCES

1. Arbeille, P., G. Fomina, J.M. Pottier, V. Bystrov, F. Patat, N. Kokova, L. Stroganova, L. Pourcelot, O. Atkov, and A. Guell. "Cardiovascular disturbances induced by a 25 days space flight and a one month head down tilt." The Physiologist, vol. 34, 1991.

2. Arbeille, Ph., J.M. Pottier, G. Fomina, A. Roncin, and A. Kotovskaya. "Assessment of the inflight cardiovascular adaptation and deconditioning. (14 day Antares space flight)." The Physiologist (submitted, 1994).

3. Barer, A.S., A.P. Savinov, G.I. Severin, A. Yu. Stoklitskiy, and Ye.P. Tikhomirov. "Physiological and hygienic substantiation for the design of individual means for preventing the adverse effect of weightlessness." Kosm. Biol. Aviakosm. Med. (English translation) 9(1):41-47, 1975.

4. Blomqvist, C.G., and H.L. Stone. "Cardiovascular adjustments to gravitational stress." In: Handbook of physiology; section 2 (the Cardiovascular System), vol. III. Edited by Shepherd, J.T., and Abboud, F.M. Bethesda, MD: American Physiological Society, pp. 1025-1063, 1983.

5. Bungo, M.W., J.B. Charles, and P.C. Johnson, Jr. "Cardiovascular deconditioning during space flight and the use of saline as a countermeasure to orthostatic intolerance." Aviat. Space Environ. Med. 56:985-990, 1985.

6. Bungo, M.W., J.B. Charles, J. Riddle, J. Roesch, D. Wolf, and M.R. Seddon. "Echocardiographic Investigation of the Hemodynamics of Weightlessness." Journal of the American College of Cardiology 7(2):192A, 1986.

7. Charles, J.B., and C.M. Lathers. "Cardiovascular adaptation to space flight" J. Clin. Pharmacol. 31:1010-1023, 1991.

8. Charles, J.B., and M.M. Jones. "DSO 478: LBNP Countermeasure to reduce post-space flight orthostatic intolerance." In: EDOMP Status Report NASA Johnson Space Center, Houston, TX, Aug., 1993. pp. 7-9.

9. Degtyarev, V.A. and V.M. Khayutin. "Condition of the human cardiovascular system in true and simulated weightlessness." NASA Technical Translation, 1971.

10. Degtyarev, V.A., V.G. Doroshev, Z.A. Kirillova, N.A. Lapshina, S.I. Ponomarev, and O.B. Kulikov. "Hemodynamics and phase structure of the cardiac cycle in members of the first crew of *Salyut-5* at rest." Kosm. Biol. Aviakosm. Med. (English translation) 14(4):11-16, 1980.

11. Fortney, S.M. "Development of lower body negative pressure as a countermeasure for orthostatic intolerance." J. Clin. Pharmacol. 31: 888-92, 1991.

12. Fritsch, J.M., J.B. Charles, B.S. Bennett, M.M. Jones, D.L. Eckberg. "Short-duration space flight impairs human carotid baroreceptor-cardiac reflex responses." J. Appl. Physiol. 73(2): 664-671, 1992.

13. Fritsch, J.M., T.L. Rehbein and E.J. Goodenberger. "Space flight reduces orthostatic tolerance and arterial baroreflex sensitivity in humans." FASEB (abstract), 1993.

14. Hoffler, G.W. "Cardiovascular studies of U.S. space crews: an overview and perspective." In: Cardiovascular Flow Dynamics and Measurements. Edited by: Hwang, N.H.C., and Normann, N.A. Baltimore, MD: University Park Press, 1977.

15. Hyatt, K.H., and D.A. West. "Reversal of bed rest-induced orthostatic intolerance

16. Johnson, R.L., G.W. Hoffler, A.E. Nicogossian, and S.A. Bergman. "*Skylab* experiment M-092: results of the first manned mission." Acta Astronautica 2:265-296, 1975.

17. Johnson, R.L., A.E. Nicogossian, S.A. Bergman, and G.W. Hoffler. "Lower body negative pressure: the second manned *Skylab* mission." Aviat. Space Environ. Med. 47(4):347-353, 1976.

18. Johnson, R.L., G.W. Hoffler, A.E. Nicogossian, S.A. Bergman, and M.M. Jackson. "Lower body negative pressure: third manned *Skylab* mission." In: Biomedical Results from *Skylab* (NASA SP-377). Edited by Johnston, R.S. and Dietlein, L.F. Washington, D.C., U.S. Government Printing Office, pp. 284-312, 1977.

19. Yegorov, A.D. "Results of medical studies during long-term manned flights on the orbital *Salyut-6* and *Soyuz* complex." NASA Technical Memorandum (TM-76014), 1979.

TABLE 1. DATA COLLECTION SESSIONS/FUNCTIONAL OBJECTIVES

Session Name	FO#	HW#	Scheduled Day	Actual Day	Scheduled Subjects	Actual Subjects	Samples/ Parameters	Method
Mir18								
LBNP Ramp test	2	1,5, 6,9, 10,11	L-120	L-120	Subject1 Subject2 Subject3 Subject4 Subject5 Subject6	Subject1 Subject2 Subject3 Subject4 Subject5 ***	ECG, BP, Echo, LBNP Pressure	ABPM, Echo-cardiography LBNP device
LBNP Ramp test	2	2,5,6, 8,12	L-42	L-60 17-21Jan95	Subject1 Subject2 Subject3 Subject4 Subject5 Subject6	Subject1 *** Subject3 Subject4 Subject5 Subject6	ECG, BP, Echo, LBNP Pressure	ABPM, Echo-cardiography LBNP device
LBNP Ramp test	2	1,5, 6,9, 10,11	L-21	not performed	Subject1 Subject2 Subject3 Subject4 Subject5 Subject6	*** *** *** *** *** ***		
LBNP Ramp test	2	1,5, 6,9, 10,11	L-7	L-10 3-4Mar95	Subject1 Subject2 Subject3 Subject4 Subject5 Subject6	Subject1 *** Subject3 *** *** ***	ECG, BP, Echo, LBNP Pressure	ABPM, Echo-cardiography LBNP device
LBNP Ramp test	2	2,6, 8,12	MD21	MD15 30Mar95	Subject3	Subject3	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
LBNP Ramp test	2	2,6, 8,12	MD16	MD21 5Apr95	Subject2	Subject2	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
LBNP Ramp test	2	2,6, 8,12	MD22	MD23 7Apr95	Subject1	Subject1	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
LBNP Ramp test	2	2,6, 8,12	MD27	not performed	Subject2	***		
LBNP Ramp test	2	2,6, 8,12	MD47	MD47 1May95	Subject1	Subject1	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
LBNP Ramp test	2	2,6, 8,12	MD48	MD48 2May95	Subject3	Subject3	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
LBNP Ramp test	2	2,6, 8,12	MD49	not performed	Subject2	***		

TABLE 1. DATA COLLECTION SESSIONS/FUNCTIONAL OBJECTIVES

Session Name	FO#	HW#	Scheduled Day	Actual Day	Scheduled Subjects	Actual Subjects	Samples/ Parameters	Method
Mir18								
LBNP Ramp test	2	2,6, 8,12	not scheduled	MD53 7 May 95	added at crew request	Subject3	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
LBNP Ramp test	2	2,6, 8,12	MD84	MD85 8 Jun 95	Subject1	Subject1	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
LBNP Ramp test	2	2,6, 8,12	MD83	MD98 21 Jun 95	Subject3	Subject3	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
LBNP Ramp test	2	2,6, 8,12	MD85	MD102 25 Jun 95	Subject2	Subject2	ECG, BP, LBNP Pressure	Gamma, Portapres LBNP device
STS-71								
LBNP Ramp test	2	3,4, 6,7, 10,11	FD6	FD6 2 Jul 95	Subject1 Subject2 Subject3	*** Subject2 Subject3	ECG, BP, Echo, LBNP Pressure	ABPM, Portapres Echo & LBNP devices
EOM Counter-measure	3	3,6, 7,10, 11	FD9	FD9 5 Jul 95	Subject1 Subject2	*** Subject2*	ECG, BP, LBNP Pressure	ABPM, Portapres, LBNP device
LBNP Ramp test	2	3,4, 6,7, 10,11	FD10	FD9 5 Jul 95	Subject1 Subject2 Subject3	*** *** Subject3	ECG, BP, Echo, LBNP Pressure	ABPM, Portapres Echo & LBNP devices
EOM Counter-measure	3	3,6, 7,10, 11	FD10	FD10 5 Jul 95	Subject1 Subject2 Subject3	*** Subject2* Subject3*	ECG, BP, LBNP Pressure	ABPM, Portapres, LBNP device
LBNP Ramp test	2	1,5, 6,9, 10,11	R+1	R+1 8 Jul 95	Subject1 Subject2 Subject3	*** *** Subject3	ECG, BP, Echo, LBNP Pressure	ABPM, Finapres, Echo & LBNP device
LBNP Ramp test	2	1,5, 6,9, 10,11	R+1	R+2 9 Jul 95	Subject1 Subject2 Subject3	Subject1 Subject2 ***	ECG, BP, Echo, LBNP Pressure	ABPM, Finapres, Echo & LBNP device
LBNP Ramp test	2	1,5, 6,9, 10,11	R+4	R+4 11 Jul 95	Subject1 Subject2 Subject3	*** *** Subject3	ECG, BP, Echo, LBNP Pressure	ABPM, Finapres, Echo & LBNP device
LBNP Ramp test	2	1,5, 6,9, 10,11	R+13	R+12 19 Jul 95	Subject1 Subject2 Subject3**	Subject1 *** ***	ECG, BP, Echo, LBNP Pressure	ABPM, Finapres, Echo & LBNP device
LBNP Ramp test	2	1,5, 6,9, 10,11	makeup session	R+42	mekup session	Subject3	ECG, BP, Echo, LBNP Pressure	ABPM, Finapres, Echo & LBNP device

* Russian countermeasure

** Subject3 session rescheduled

*** Not performed

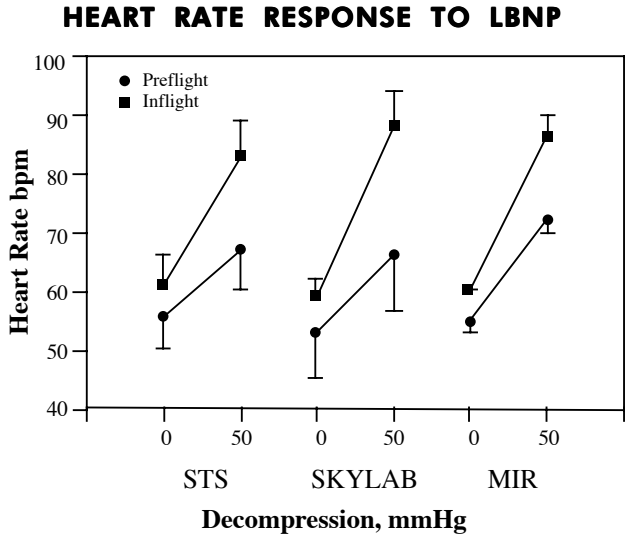


Figure 1. Averaged Heart Rate data from preflight and inflight LBNP "ramp" tests on Shuttle (<15 days), Skylab (28-84 days) and Mir (110 days) crewmembers. It is apparent that all three groups are similar, both preflight and in flight at their respective test times.

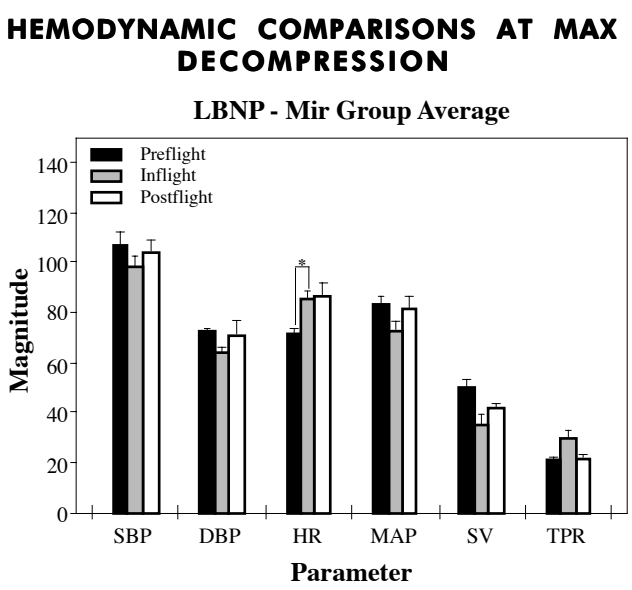


Figure 2. Preflight, inflight, and postflight comparisons of Systolic, Diastolic, and Mean Arterial Blood Pressure, Heart Rate, Stroke Volume, and Total Peripheral Resistance at maximum decompression (-50 mmHg). There is a significant increase in Heart Rate from preflight to in flight ($p=0.04$) as was expected for the three Mir crewmembers (see *). There were no significant differences in any other parameters.

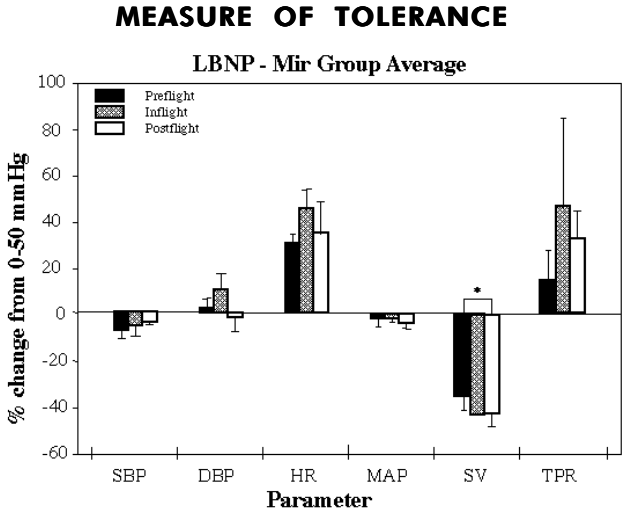


Figure 3. Measure of tolerance - Systolic, Diastolic, and Mean Arterial Blood Pressure, Heart Rate, Stroke Volume, and Total Peripheral Resistance are presented as the % change from 0-50 mmHg (control to maximum decompression). This figure illustrates the delta from baseline, thus factoring in the different endpoints for each crewmember and presenting the result as a group average. The change in Stroke Volume was significantly greater in flight and postflight compared to preflight ($p=0.02$) (see *). No other parameters exhibited a significant change, in part due to the large individual variability and small sample size. In fact, the statistical power for all of these comparisons should be considered when drawing any conclusions from these data.