FAA-AM-78-5

THREE REPORTS RELEVANT TO STRESS IN AVIATION PERSONNEL:

I. DEVELOPMENT OF THE AVIATION STRESS PROTOCOL--SIMULATION AND PERFORMANCE, PHYSIOLOGICAL, AND BIOCHEMICAL MONITORING SYSTEMS: PHASE I

II. ASSESSMENT OF CARDIOVASCULAR FUNCTION AFTER EXPOSURE TO THE AVIATION STRESS PROTOCOL--SIMULATION

III. THE RELATIONSHIP BETWEEN STRESS-RELATED METABOLITES AND DISQUALIFYING PATHOLOGY IN AIR TRAFFIC CONTROL PERSONNEL

E. A. Higgins
M. T. Lategola
C. E. Melton

Civil Aeromedical Institute
Federal Aviation Administration
Oklahoma City, Oklahoma

February 1978

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Aviation Medicine
Washington, D.C. 20591

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

IFC

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-AM-78-5		

4. Title and Subtitle	5. Report Date
THREE REPORTS RELEVANT TO STRESS IN AVIATION PERSONNEL	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s)	
E. A. Higgins, N. T. Lategola, and C. E. Melton	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
FAA Civil Aeromedical Institute P. O. Box 25082 Oklahoma City, Oklahoma 73135	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	
Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S.W. Washington, D.C. 20591	14. Sponsoring Agency Code

15. Supplementary Notes

Work was performed under approved Tasks AM-C-76-PHY-82, AM-A-76-PHY-79, and AM-A-76-PHY-86.

16. Abstract In development of the aviation stress protocol--simulation (ASPS), the following conclusions were reached: (1) In experiments using the ASPS, cardiovascular testing will be conducted in parallel, but separately; (2) The time of exposure to altitude will be limited to 2 h; and (3) Measurements such as visual accommodation, internal body temperature, blood glucose, blood drug or alcohol level, and others will be included in the ASPS only when appropriate.

Cardiovascular and pulmonary parameters were assessed under simulated +Gz and exercise conditions in normal males after exposure to the ASPS. Some parameters were displaced to a statistically significant degree, but such displacements are of doubtful physiological significance because of the unavoidable time lapse between altitude exposure and assessment. These preliminary experiments served to demonstrate that meaningful physiological assessments can only be made during exposure to the altitudes specified in the ASPS.

Thirty-six controller subjects from previous stress studies were identified who subsequently suffered medical conditions severe enough to require waiver or retirement. These subjects' stress indices were compared with those of subjects who had no known pathology to see if any of the stress indicators were predictive of pathological conditions. The data showed that controllers who developed gastrointestinal pathology had significantly ($p < 0.01$) higher c_{st} than did their normal counterparts. At Miami ARTCC, c_{ne} was significantly elevated ($p < 0.05$) in the cardiovascular group.

17. Key Words	18. Distribution Statement
Aviation Stress Protocol--Simulation, Aeromedical Certification, Aeromedical Standards, Cardiovascular Function, Physiological Monitoring, Biochemical Monitoring, Stress, and Air Traffic Controller.	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	34	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

DEVELOPMENT OF THE AVIATION STRESS PROTOCOL--SIMULATION AND PERFORMANCE, PHYSIOLOGICAL, AND BIOCHEMICAL MONITORING SYSTEMS: PHASE I

I. Introduction.

The Federal Air Surgeon, in his FY-75 Call for Estimates, said, "I have determined that the highest priority will be research in support of medical certification and medical standards development." In response to this priority statement, the Aviation Physiology Laboratory began to design a broad research program to provide clinical aviation medicine with information needed for medical certification decisions and for developing and revising medical standards.

The Aviation Stress Protocol--Simulation (ASPS) focuses on the fact that any assessment of fitness in pilots and air traffic controllers must take into account their potential for impaired performance. Not only must they perform their routine tasks at optimal levels for prolonged periods of time, but these persons must also retain the capacity to respond to task overloads in emergency situations. For pilots, there must be a normal tolerance to flight environmental stressors, particularly to the range of altitudes where general aviation pilots can fly without their requiring supplemental oxygen.

Because performance was an important consideration, performance measurements were made using the Civil Aeromedical Institute (CAMI) Multiple Task Performance Battery (MTPB) (1).

II. Experiment Design.

Healthy, male, paid volunteers (aged 21 to 28 years) served as test subjects. Interviews and physical examinations were conducted for all prospective subjects prior to selection. After selection, subjects were trained on the MTPB equipment and the vision testing equipment. Subjects were then tested individually in the CAMI research altitude chamber at each of four simulated altitudes. These (MSL) altitudes to which the subjects were exposed in random sequence were ground level, 8,000 ft, 10,500 ft, and 12,500 ft. Subjects reported to the laboratory without eating breakfast and were given a standard meal before beginning the experiment. After breakfast, subjects completed a sleep survey and a subjective rating scale

(Figure 1). Electrodes were attached to the subjects for heart rate recordings, and subjects were given a thermistor rectal probe for self-insertion for rectal temperature measurements. The subjects then reported to the altitude chamber for a 3-h test session. Heart rate was recorded continuously, rectal temperature and blood pressure were measured once during each 15-min period, and tests of visual accommodation (provided by Dr. K. W. Welsh of the Aviation Physiology Laboratory) were administered before the session and at the end of each hour. Capillary blood samples from finger punctures were drawn before and after each test session for determinations of blood glucose and hematocrit. At the end of the 3-h test, subjects filled out a symptom checklist (Figure 2) and again executed a subjective rating scale (Figure 3). At the end of the 3-h test, urine was collected for measurements of epinephrine, norepinephrine, and 17-ketogenic steroids (2). After each chamber session, subjects were given a cardiovascular evaluation.

During each 3-h test session, the subjects performed four different combinations of tasks of the MTPB in 1-h cycles. (For a complete description of the tasks, see Jennings, Chiles and West(1).) Lights and meters monitoring tasks were performed throughout the test session. During the first 15 min of the hour, tracking arithmetic tasks were performed. During the second 15 min, arithmetic and problem solving were performed. During the third 15 min, pattern discrimination and problem were performed. And, during the final 15 min, pattern discrimination and tracking were performed. This sequence was then repeated during the second and third hours of the test session. The measure of performance used was an equal-variance composite of the various time and accuracy measures from the individual tasks.

Twelve subjects were selected and 10 completed the test series. Data collection was accomplished in three periods: March 15 to April 16, June 1 to June 24, and June 28 to August 2, 1976.

III. Results.

The sleep surveys indicated no difference in the quality or quantity of the subjects' sleep prior to the test days.

According to the results of the subjective rating scales, attentiveness decreased significantly from the beginning to

Name_____ Subject No._____ Period _____ Condition _____ Study_____

Think of how you feel right now and rate your feelings, attitudes, and emotions by circling the number which best describes them.

1	2	3	4	5	6	7	8	9
Very Attentive		Quite Attentive		Attentive		Inattentive		Very Inattentive
1	2	3	4	5	6	7	8	9
Very Wide Awake and Energetic		More Pep Than Usual		About My Usual Level of Energy		More Tired Than Usual		Very Tired and Sleepy
1	2	3	4	5	6	7	8	9
Very Strained		Strained		Indifferent		Relaxed		Completely Relaxed
1	2	3	4	5	6	7	8	9
Extremely Bored		Moderately Bored		Indifferent		Moderately Interested		Extremely Interested
1	2	3	4	5	6	7	8	9
Extremely Irritated		Quite Irritated		Moderately Annoyed		Mildly Annoyed		Indifferent

FIGURE 1. Subjective rating scale A.

SYMPTOMS	DEGREE*			WHEN OCCURRED
	mild	mod.	severe	hr.-1 hr.-2 hr.-3
Difficult Concentration	☐	☐	☐	☐☐☐
Difficult Coordination	☐	☐	☐	☐☐☐
Drowsiness	☐	☐	☐	☐☐☐
Arm/Hand Fatigue	☐	☐	☐	☐☐☐
Headache	☐	☐	☐	☐☐☐
throbbing-forehead ☐ temples ☐ top of head ☐ back of head ☐				☐☐☐
ache -forehead ☐ temples ☐ top of head ☐ back of head ☐				☐☐☐
sharp pains-forehead ☐ temples ☐ top of head ☐ back of head ☐				☐☐☐
Visual Symptoms				
blurring	☐	☐	☐	☐☐☐
double vision	☐	☐	☐	☐☐☐
eye fatigue or aching	☐	☐	☐	☐☐☐
Hearing Symptoms				
muffling of sounds	☐	☐	☐	☐☐☐
buzzing sound	☐	☐	☐	☐☐☐
Other Symptoms				
happiness	☐	☐	☐	☐☐☐
depression	☐	☐	☐	☐☐☐
irritability	☐	☐	☐	☐☐☐
recurring thoughts	☐	☐	☐	☐☐☐
detachment feeling	☐	☐	☐	☐☐☐
dizziness	☐	☐	☐	☐☐☐

* Mild - not of sufficient degree to impair performance
  Moderate - of sufficient degree to possibly impair performance
  Severe - of sufficient degree to definitely impair performance

Observer's Comments:

FIGURE 2. Symptom checklist.

Name _____ Subject No. _____ Period _____ Condition _____ Study _____

Think of how you felt near the end of the task period you just completed. Rate your feelings, attitudes, and emotions by circling the number which best describes them. It is important that you try to rate how you felt while still performing the task, and not how you may feel right now.

1	2	3	4	5	6	7	8	9
Very Attentive		Quite Attentive		Attentive		Inattentive		Very Inattentive
Very Wide Awake and Energetic		More Pep Than Usual		About My Usual Level of Energy		More Tired Than Usual		Very Tired and Sleepy
Very Strained		Strained		Indifferent		Relaxed		Completely Relaxed
Extremely Bored		Moderately Bored		Indifferent		Moderately Interested		Extremely Interested
Extremely Irritated		Quite Irritated		Moderately Annoyed		Mildly Annoyed		Indifferent

FIGURE 3. Subjective rating scale B.

the end of the 3-h experiment at both 8,000 ft and 12,500 ft (Figure 4); a corresponding decrease in energy level was reported (Figure 5). Interest decreased with time of exposure at all altitudes, with statistical significance at the 0.05 level for ground level and 8,000 ft and at the 0.01 level for 10,500 and 12,500 ft (Figure 6).

Concentration difficulty and drowsiness were the most frequently reported symptoms on the checklist; more subjects reported these two symptoms for 12,500 ft than for the other altitudes.

The visual accommodation tests yielded no statistically significant findings attributable to either altitude or duration of the test.

Hematocrit demonstrated a slight but statistically insignificant hemoconcentration through time at each of the four altitudes. The blood glucose was significantly less at the end of the experiments than at the beginning, but there were no differences attributable to altitude (Figure 7).

There was a statistically significant increase in heart rate with increasing altitude (Figure 8). There were no statistically significant differences for systolic blood pressure, but diastolic pressure did demonstrate a statistically significant decrease ($p \leq .05$) at 12,500 ft (Figure 9).

The findings of the urine analyses are presented in Table 1.

Although the catecholamines, epinephrine, and norepinephrine demonstrated increasing values with each increase in altitude, the individual variances were large and the differences did not prove to be statistically significant.

The performance data from the MTPB exhibited great variability with no effects that could be attributed to altitude. In addition, the performance levels, when averaged over altitude conditions, showed a significant drop as a function of the number of test sessions experienced. Apparently, the subjects were losing interest in, or losing motivation to comply with the demands of the experiment.

IV. Discussion.

The series of experiments conducted during the development of the ASPS provided information indicating a need for

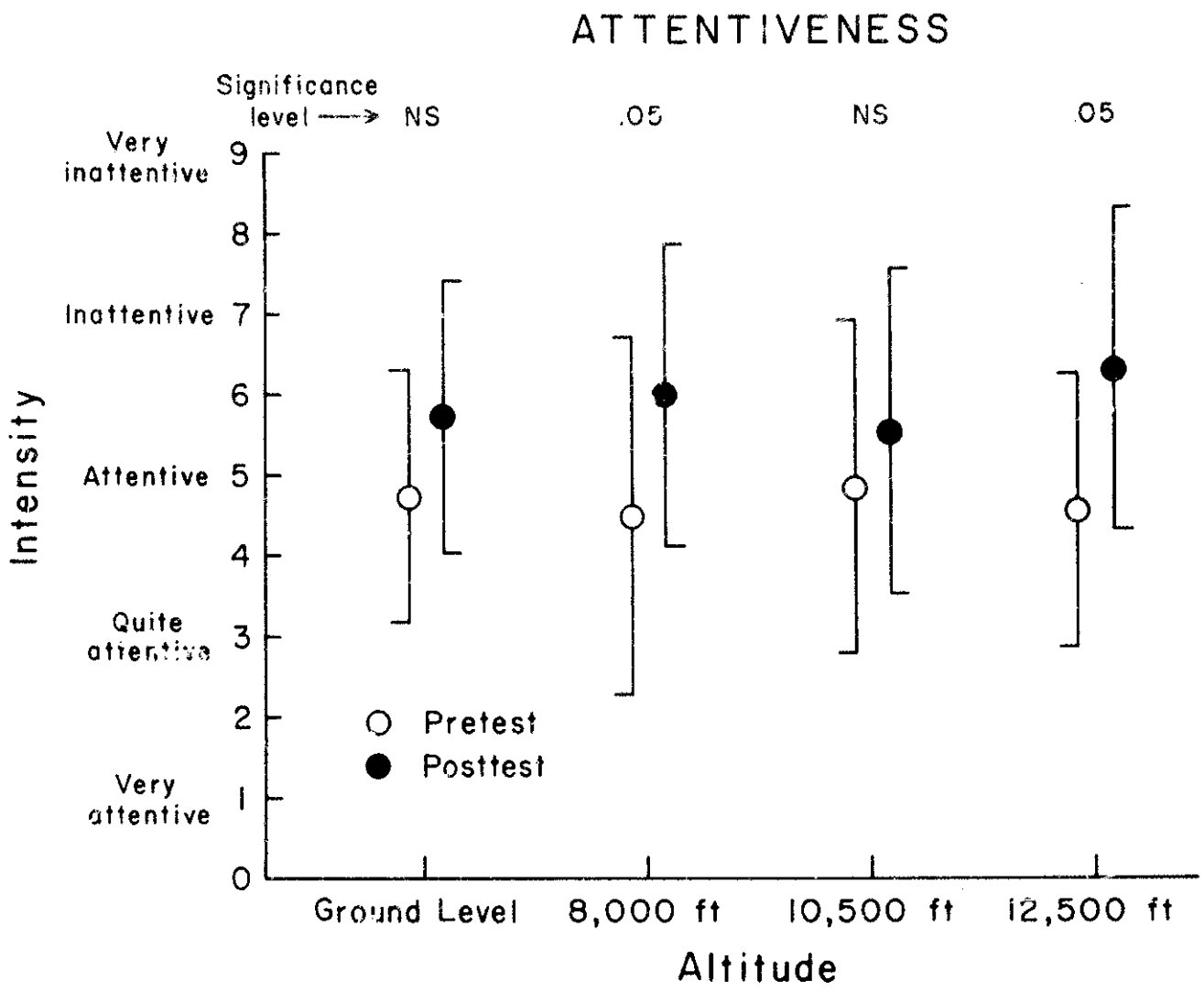

FIGURE 4. Pretest and posttest levels of attentiveness as a function of altitude (N = 10).

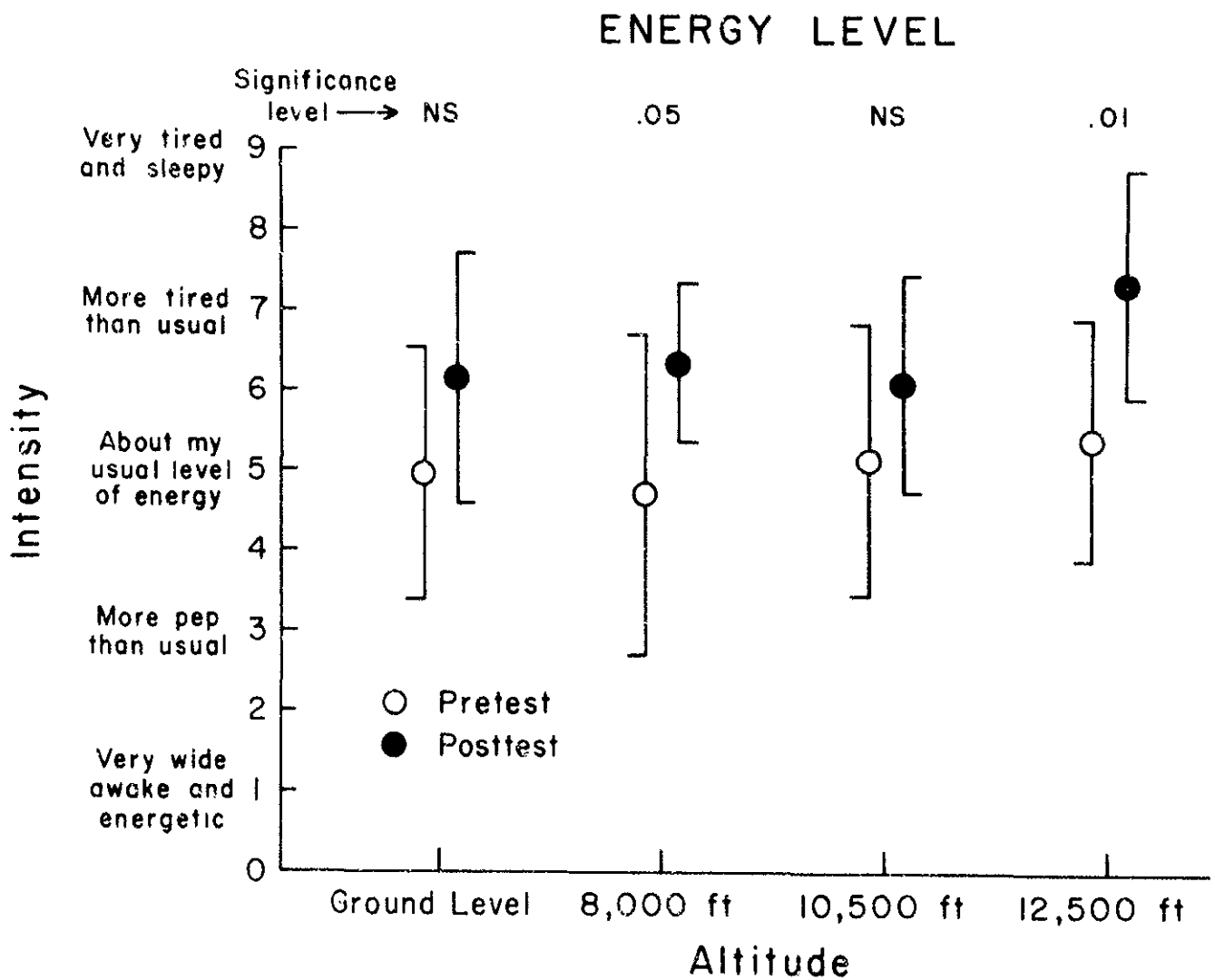

FIGURE 5. Pretest and posttest levels of energy as a function of altitude (N = 10).

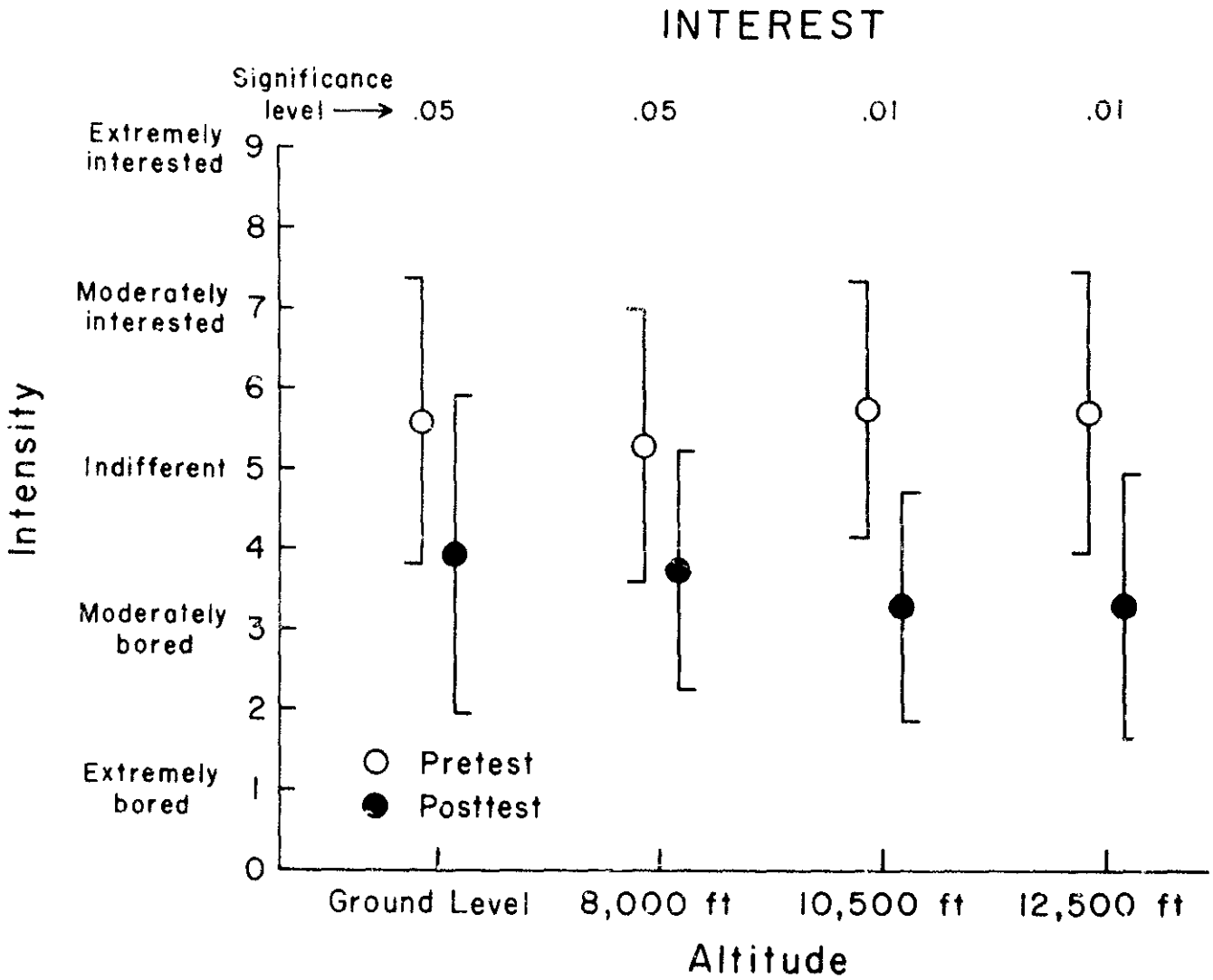

FIGURE 6. Pretest and posttest levels of interest as a function of altitude (N = 10).

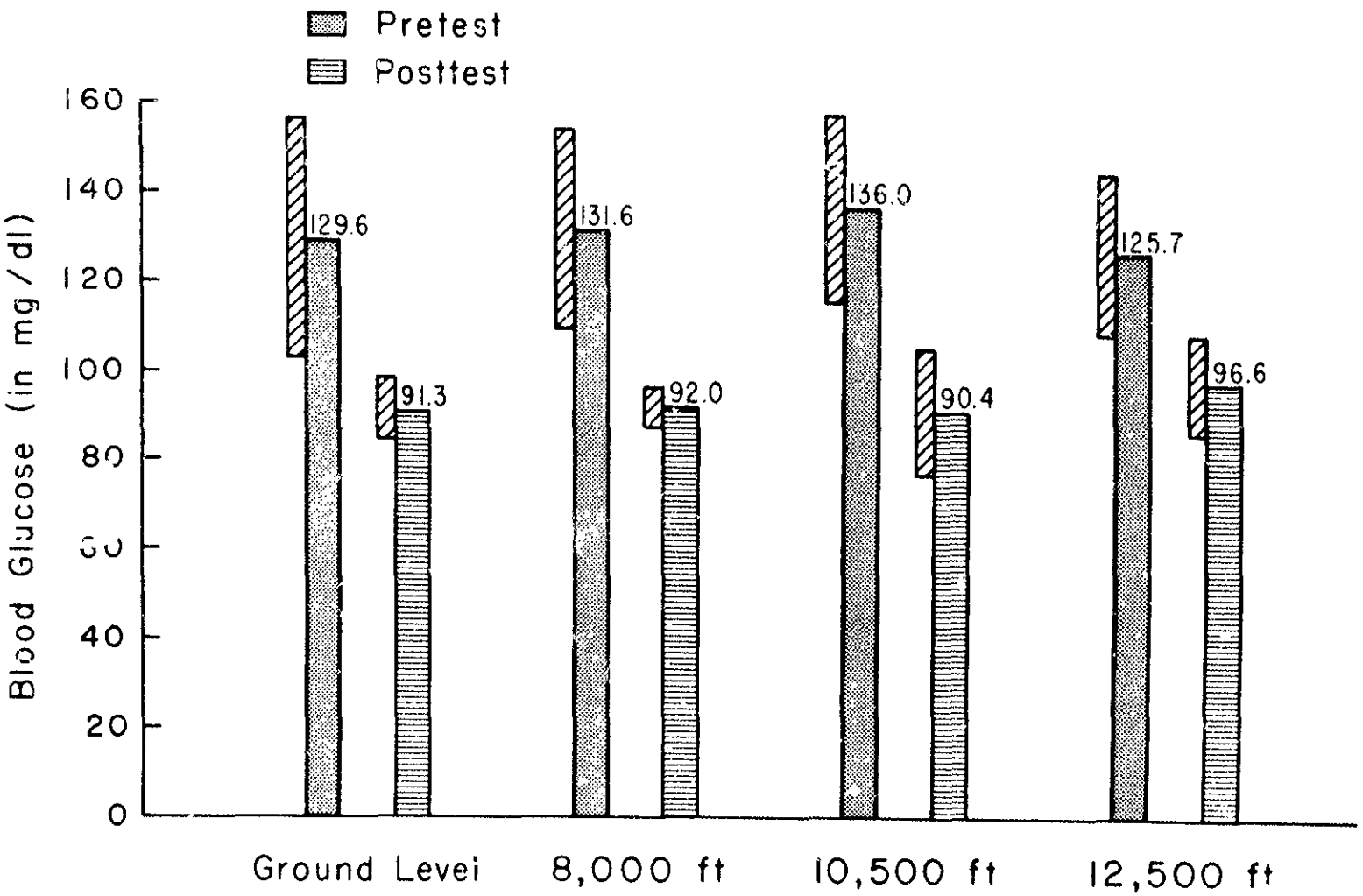

FIGURE 7. Pretest and posttest values for blood glucose (mean ± standard deviation) as a function of altitude (N = 10).

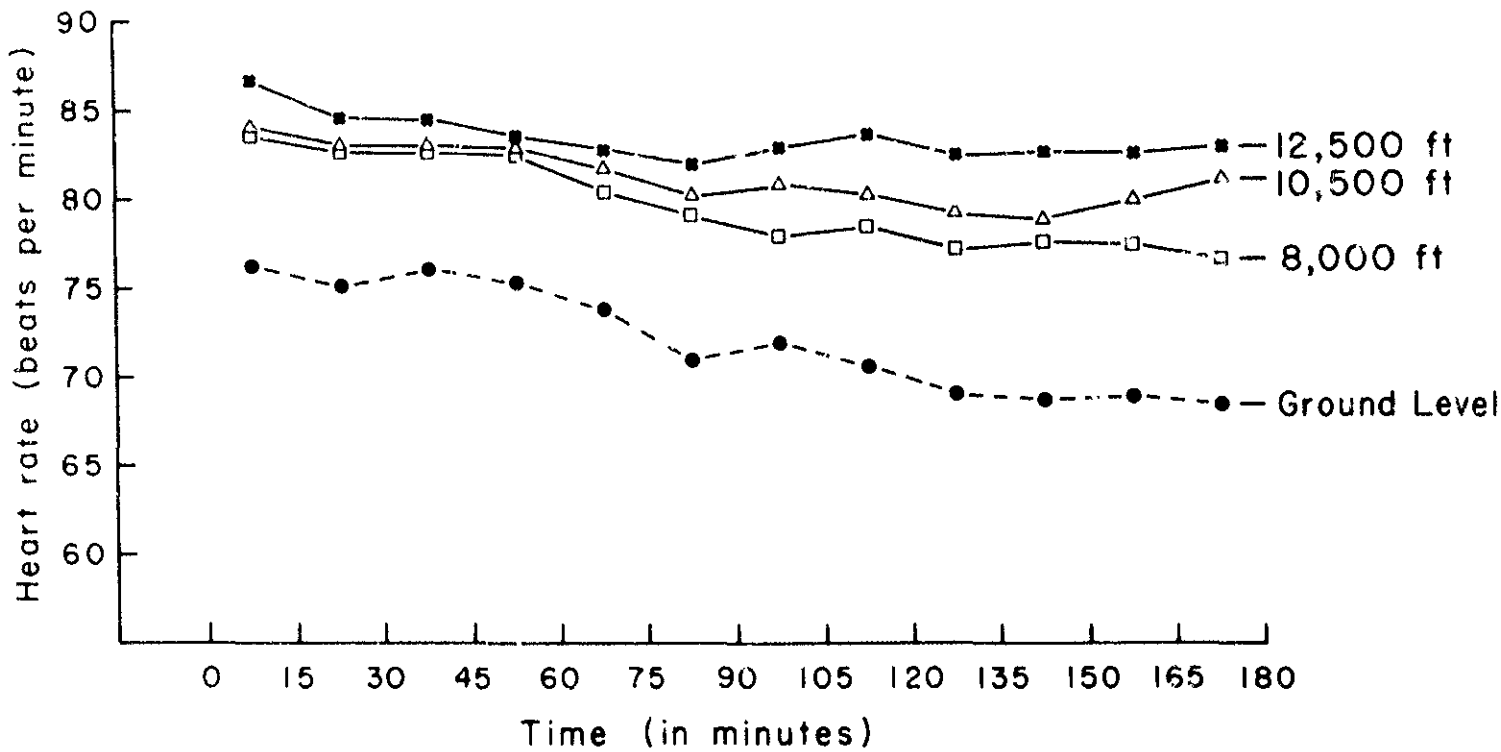

FIGURE 8. Mean heart rate values through time as a function of altitude (N = 10).

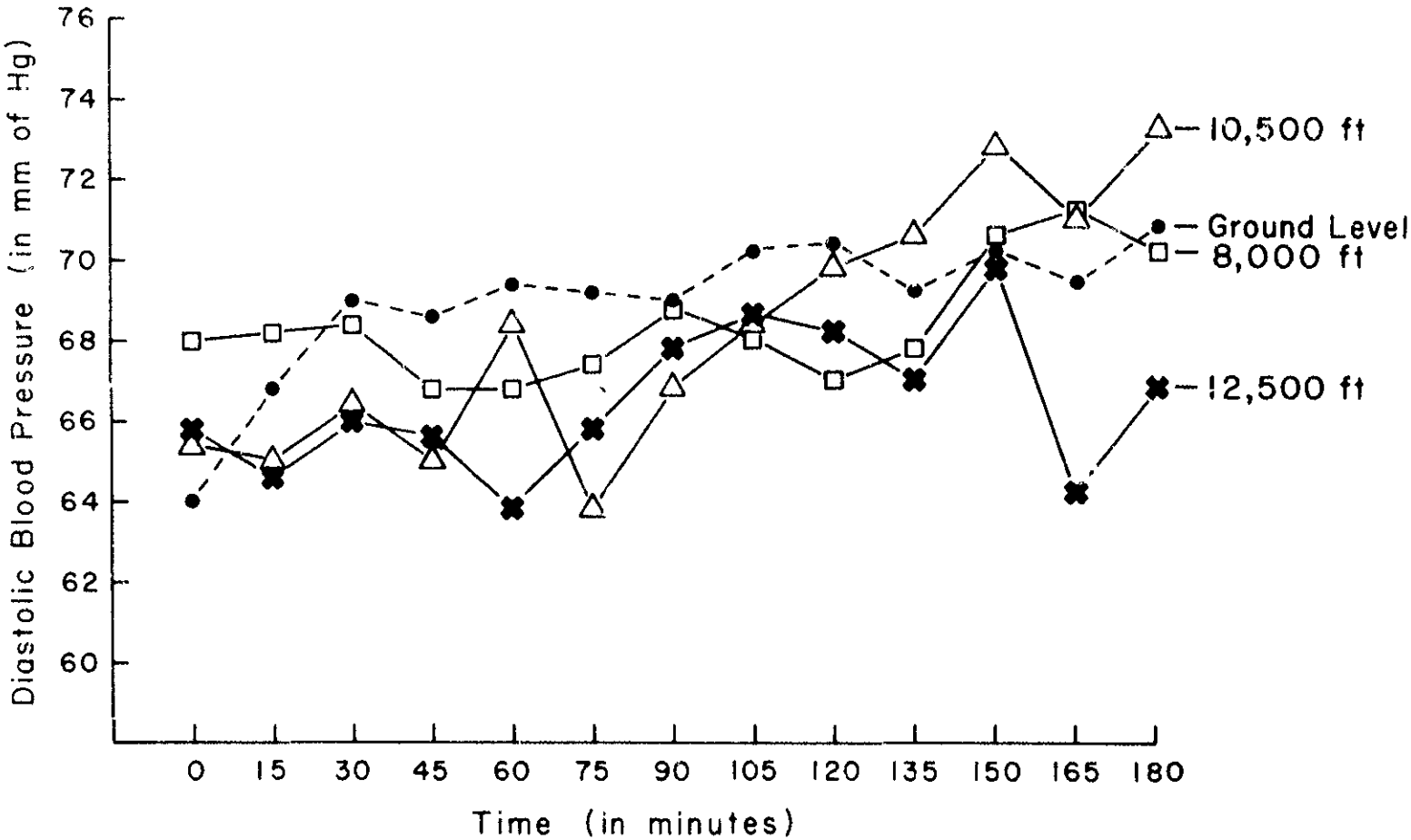

FIGURE 9. Mean values of diastolic blood pressure through time as a function of altitude (N = 10).

TABLE 1. Mean Values* and Standard Deviations* for Urinary Hormones

Altitude (MSL)	Epinephrine (ng/h)	Norepinephrine (ng/h)	17-Ketogenic Steroids (mg/h)
Ground Level	575.2 ±166.0	1725.1 ±386.3	0.6959 ±0.1361
8,000 Feet	651.3 ±174.1	1864.0 ±526.5	0.6014 ±0.1446
10,500 Feet	745.5 ±338.6	2100.6 ±642.4	0.6695 ±0.1322
12,500 Feet	797.1 ±386.1	2213.6 ±442.9	0.6918 ±0.2590

* N = 10

refinement of the protocol. Results of some of the subjective rating scales showed that increasing altitude accentuated changes that occurred primarily as a result of the long experimental procedure; i.e., interest decreased more at the two higher altitudes. Further, concentration difficulty and drowsiness were reported most frequently at 12,500 ft.

In mid-August 1976, conferences were held by Drs. Busby, Melton, Collins, Chiles, Lategola, and Higgins to evaluate the findings to that time. The general conclusions were:

A. The experiments were too long and too complicated.

B. The experiment protocol itself probably had greater effect on the subjects' responses than did the differences in altitude.

C. The data obtained from the MTPB and cardiovascular testing were not conclusive.

D. Further refinement of the protocol is indicated. In future experiments, the cardiovascular testing should be conducted separately, in parallel with other testing, and not at the end of an already long test procedure.

E. The time spent in the altitude chamber for a test session should be reduced to 2 h to preclude the boredom and fatigue associated with the longer testing procedure.

F. Additional tests should be conducted to determine the sensitivity of the MTPB for detecting differences due to altitude alone.

Between August 28 and November 18, 1976, shorter tests (2 h) were conducted at three altitudes; ground level, 12,500 ft, and 14,000 ft. Ten subjects were evaluated. The cardiovascular testing, visual accommodation tests, dietary control, and blood sampling were eliminated from the protocol. This series of tests was conducted primarily to evaluate the effects of altitude on complex performance. Unfortunately, subject motivation again appeared to fluctuate widely and again, altitude did not have a significant effect on performance. In the past, the problem was produced by rather frequent MTPB equipment malfunctions.

V. Conclusion.

In future experiments using the ASPS, the cardiovascular testing will be conducted separately. The time of exposure to altitude and MTPB testing will be limited to 2 h. Measurements such as visual accommodation, internal body temperature, blood glucose, blood drug or alcohol level, and others will be included in the ASPS experiments only when appropriate.

REFERENCES

1. Jennings, A. E., W. D. Chiles, and G. West: Methodology in the Measurement of Complex Human Performance: Two-Dimensional Compensatory Tracking, FAA Office of Aviation Medicine Report No. AM-72-21, 1972.

2. Melton, C. E., J. M. McKenzie, B. D. Polis, S. M. Hoffmann, and J. T. Saldivar, Jr.: Physiological Responses in Air Traffic Control Personnel: Houston Intercontinental Tower, FAA Office of Aviation Medicine Report No. AM-73-21, 1973.

REFERENCES

1. Jennings, A. E., W. D. Chiles, and G. West: Methodology in the Measurement of Complex Human Performance: Two-Dimensional Compensatory Tracking, FAA Office of Aviation Medicine Report No. AM-72-21, 1972.

2. Melton, C. E., J. M. McKenzie, B. D. Polis, S. M. Hoffmann, and J. T. Saldivar, Jr.: Physiological Responses in Air Traffic Control Personnel: Houston Intercontinental Tower, FAA Office of Aviation Medicine Report No. AM-73-21, 1973.

ASSESSMENT OF CARDIOVASCULAR FUNCTION AFTER EXPOSURE TO THE AVIATION STRESS PROTOCOL--SIMULATION

I. Introduction.

The Aviation Stress Protocol--Simulation (ASPS) was designed to assess the potential for impaired performance by testing the capacity of pilots and air traffic controllers to: (i) maintain an optimum performance level for a prolonged period of time and (ii) respond to a task overload or emergency situation. For pilots, this capability includes the assessment of tolerance to flight environmental stresses in the range of altitudes to which general aviation pilots can legally fly without supplemental oxygen. The core of the ASPS (for pilots) is the exposure of the individual for single-day 3-h periods to a battery of simulated complex psychomotor tests (MTPB) at ground level (GL) and chamber altitudes at 8,000 (A), 10,500 (B), and 12,500 (C) feet (MSL). During the ASPS, task performance is monitored for deterioration of psychomotor performance and physiological and biochemical tests are administered to identify possible causes of such deterioration.

As an adjunct procedure, cardiovascular tests were administered immediately following the ASPS to identify any functional deterioration due to the ASPS exposure per se. This report will deal only with the post-ASPS cardiovascular testing.

II. Methods.

The cardiovascular test battery consisted of: (i) a test of orthostatic tolerance using a lower body negative-pressure (LBNP) box (supine) and (ii) a submaximum physical workload test using standardized, upright, seated, bicycle ergometry. The LBNP load and time sequences were a 3-min rest period, a 2-min exposure to -25 mm Hg LBNP (≃ +1.5 Gz), a 2-min recovery/rest period, and a 2-min exposure to -50 mm Hg LBNP (≃ +2.0 Gz). The ergometry load and time sequences were a 5-min rest period, a 3-min exposure to a 50 rpm/30 W workload, and a 3-min exposure to a 50 rpm/60 W workload. Parameters assessed during the LBNP test were pulmonary ventilation (using direct spirometry), heart rate (HR) and electrocardiogram (single-lead ECG), blood pressure (automatic sphygmomanometry), and temporal artery flow velocity (directional

Doppler equipment). During ergometry testing, the same parameters were assessed excepting the omission of the temporal artery flow velocity and the addition of oxygen uptake (analysis of quantitatively collected expired air).

Immediately following a given ASPS altitude exposure, the subject (seated in a wheelchair at all times) was "finger pricked" for microsampling of blood, wheeled to a private room for quantitative collection of urine, and then delivered to the cardiovascular testing room. The average elapsed time between the end of altitude exposure and start of the LBNP and ergometry tests were 44 and 63 min respectively.

A complete set of ASPS altitude exposures was achieved on a total of 10 normal male subjects (21-25 yr of age). The GL data served as baselines for comparing displacements due to altitudes A, B, and C.

III. Results.

LBNP. Both levels of +Gz exposure were well tolerated by all subjects without syncope or temporal artery flow reversal. Although syncope was absent, physiological displacements did occur in all subjects. In general, the displacements increased in rough proportion to the applied level of +Gz and the preceding altitude exposure. The quantitative altitude-related displacements of the systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), HR, temporal artery flow velocity (TAFV), and pulmonary ventilation ($\dot{V}_E$) are summarized in Tables 1-3. The SBP dropped during each +Gz exposure, but the drops and overall levels appeared to be approximately the same for GL as for preceding altitudes A, B, and C as compared to GL. The PP generally dropped during each +Gz exposure, and the overall levels were also lower following altitudes A, B, and C as compared to GL. The HR increased during each +Gz exposure, and the overall levels were also higher following altitudes A, B, and C as compared to GL. In each of the two +Gz exposures and the two preceding rest periods, most of the altitude-related increases in HR (A, B, and C compared to GL) were statistically significant ($p \leq 0.05$). In the altitude context of comparison, four of the DBP and two of the PP displacements were also significant.

The TAFV dropped during each +Gz exposure, but the overall levels were substantially higher following altitudes A, B, and

TABLE 1. SBP and DBP Responses to +1.5 and +2.0 Gz at Ground Level, and at 8,000, 10,500, and 12,500 Ft Altitudes

		LBNP							
		SBP (mm Hg)				DBP (mm Hg)			
		R	+1.5 Gz	R	+2.0 Gz	R	+1.5 Gz	R	+2.0 Gz
Ground Level (Control)	m	117.1	115.7	118.1	111.8	65.1	65.5	68.1	64.5
	SE	3.1	3.0	3.8	3.5	1.7	1.9	2.0	2.1
8,000 ft (% of Control)	m	100.6	98.6	99.8	99.1	107.1*	108.6*	103.9	108.1
	SE	1.5	1.7	2.4	2.4	2.6	2.1	3.2	4.0
10,500 ft (% of Control)	m	102.4	100.1	102.1	104.8	108.3*	105.4	102.4	109.4*
	SE	1.9	2.2	2.7	2.8	3.7	2.4	3.1	2.3
12,500 ft (% of Control)	m	99.9	100.2	100.6	100.5	104.1	102.9	104.5	108.4
	SE	1.3	3.4	2.8	3.3	2.2	3.0	3.4	4.6

TABLE 2. PP and HR Responses to +1.5 and +2.0 Gz at Ground Level, and at 8,000, 10,500, and 12,500 Ft Altitudes

		LBNP							
		PP (mm Hg)				HR (bpm)			
		R	+1.5 Gz	R	+2.0 Gz	R	+1.5 Gz	R	+2.0 Gz
Ground Level (Control)	m	52.1	50.2	50.0	47.3	55.8	56.7	58.2	65.0
	SE	2.4	3.1	3.4	4.2	2.3	2.2	2.8	2.6
8,000 ft (% of Control)	m	92.7*	86.4*	98.2	95.7	104.8*	108.3*	105.1*	105.8
	SE	2.5	3.3	5.6	8.4	1.9	3.2	3.6	4.0
10,500 ft (% of Control)	m	95.5	94.4	102.2	101.9	108.4*	112.2*	107.0*	110.5*
	SE	3.2	3.9	3.3	7.0	2.1	3.1	3.0	4.1
12,500 ft (% of Control)	m	95.0	95.2	96.6	93.1	108.4*	107.4	106.6	104.3
	SE	3.0	6.6	5.4	6.9	3.4	3.4	3.1	4.3

TABLE 3. $\dot{V}_E$ and TAFV Responses to +1.5 and +2.0 Gz at Ground Level, and at 8,000, 10,500, and 12,500 Ft Altitudes

		LBNP							
		$\dot{V}_E$ (lpm)				TAFV (cm/s)			
		R	+1.5 Gz	R	+2.0 Gz	R	+1.5 Gz	R	+2.0 Gz
Ground Level (Control)	m	7.6	7.2	7.6	8.8	9.7	8.9	8.1	7.8
	SE	0.5	0.6	0.4	0.8	1.6	2.1	1.3	1.5
8,000 ft (% of Control)	m	101.8	112.8	106.9	99.0	108.4	131.7	143.8	149.4
	SE	9.3	12.0	10.6	8.2	14.6	21.9	28.5	31.2
10,500 ft (% of Control)	m	103.3	98.9	98.5	101.7	139.6	225.2	233.2	318.8
	SE	9.6	9.7	7.1	8.9	28.5	99.6	103.1	170.1
12,500 ft (% of Control)	m	99.1	121.1	107.2	94.1	137.8	188.0	223.6	258.8
	SE	8.0	17.0	6.7	9.1	19.2	59.3	81.3	114.6

C compared to GL. None of the observed blood flow velocity displacements was statistically significant. The $\dot{V}_E$ response to each +Gz exposure varied widely in direction and magnitude with no obvious consistent relationship to either +Gz or altitude.

Ergometry. Both the 30- and 60-W workloads were comfortably tolerated by all subjects. The SBP, DBP, PP, HR, $\dot{V}_E$, and oxygen uptake ($\dot{V}_{O_2}$) increased generally in direct proportion to the applied ergometric load. With the exception of PP, the overall levels of these parameters were higher following altitudes A, B, and C as compared to GL. The overall levels of PP were lower following altitudes A, B, and C as compared to GL. The quantitative altitude-related displacements of the SBP, DBP, PP, HR, $\dot{V}_E$, and $\dot{V}_{O_2}$ are summarized in Tables 4-6. Statistically significant ($P \leq 0.05$) altitude-related changes occurred: (i) in DBP, PP, HR, and $\dot{V}_{O_2}$ in the preergometric rest period; (ii) in DBP, PP, and HR during the 30-W workload; and (iii) in HR and $\dot{V}_E$ during the 60-W workload.

IV. Discussion.

Some statistically significant altitude-related displacements in physiological parameters appeared in both the LBNP and ergometry segments of the post-ASPS cardiovascular assessment, even though these two testing segments nonoptionally followed the end of altitude exposure by an average of 44 and 63 min respectively. Because these displacements could possibly be accentuated by closer temporal proximity of the cardiovascular testing to the altitude exposures, it was decided that the cardiovascular testing would henceforth be run in parallel rather than in tandem with the core ASPS. The cardiovascular tests are to be applied at GL and during appropriate altitude exposures rather than after the altitude exposures. During the currently extended "shakedown" Phase I testing of the core ASPS, the paralleling cardiovascular equipment and protocol will be shifted to one of the small altitude chambers. We should be ready to resume full-scale parallel testing when the core ASPS commences its Phase II operations. Running this test in parallel with the core ASPS tests further has the beneficial effect of relieving the tedium of the core tests by reducing the length of subject exposure.

TABLE 4. SBP and DBP Responses to 30W and 60W Bicycle Ergometry Workloads at Ground Level, and at 8,000, 10,500, and 12,500 Ft Altitudes

		ERGOMETRY					
		SBP (mm Hg)			DBP (mm Hg)		
		R	30 W	60 W	R	30 W	60 W
Ground Level (Control)	m	116.4	128.6	138.6	64.9	66.1	69.8
	SE	3.0	3.6	3.6	2.2	2.5	3.2
8,000 ft (% of Control)	m	100.5	99.2	102.4	106.7*	107.0*	104.6
	SE	1.9	0.8	1.8	2.6	2.1	3.5
10,500 ft (% of Control)	m	100.5	100.2	100.4	106.2*	112.0*	106.0
	SE	1.3	1.9	1.8	2.3	3.2	2.7
12,500 ft (% of Control)	m	101.6	100.0	102.4	109.6	106.0	106.9
	SE	2.7	2.7	2.1	5.9	5.2	5.8

TABLE 5. PP and HR Responses to 30W and 60W Bicycle Ergometry Workloads at Ground Level, and at 8,000, 10,500, and 12,500 Ft Altitudes

		ERGOMETRY					
		PP (mm Hg)			HR (bpm)		
		R	30 W	60 W	R	30 W	60 W
Ground Level (Control)	m	51.6	62.5	68.8	58.8	77.9	94.2
	SE	3.2	3.7	3.9	2.1	3.1	2.4
8,000 ft (% of Control)	m	88.4	91.8*	103.0	105.6	102.6	102.6
	SE	5.7	1.4	4.5	3.3	2.7	2.2
10,500 ft (% of Control)	m	89.5	90.7*	95.9	107.7*	105.1	104.2*
	SE	5.1	4.0	3.8	2.6	3.0	1.5
12,500 ft (% of Control)	m	87.7*	95.8	100.3	108.5*	108.5*	106.0*
	SE	4.6	3.8	4.3	3.0	3.3	1.8

TABLE 6. $\dot{V}_E$ and $\dot{V}_{O_2}$ Responses to 30W and 60W Bicycle Ergometry Workloads at Ground Level, and at 8,000, 10,500, and 12,500 Ft Altitudes

		ERGOMETRY					
		$\dot{V}_E$ (lpm)			$\dot{V}_{O_2}$ (ml/m/kg)		
		R	30 W	60 W	R	30 W	60 W
Ground Level (Control)	m	8.6	16.1	22.6	3.2	8.5	12.7
	SE	0.4	0.7	0.8	0.2	0.4	0.6
8,000 ft (% of Control)	m	104.3	97.2	109.1*	105.3	100.3	103.3
	SE	6.4	4.5	2.9	3.2	4.5	2.7
10,500 ft (% of Control)	m	104.2	94.3	103.8	117.9*	99.8	101.7
	SE	9.2	3.1	2.2	6.9	5.0	2.8
12,500 ft (% of Control)	m	107.4	101.8	106.8*	116.7*	105.0	108.0
	SE	3.9	6.0	2.3	5.9	5.2	4.3

THE RELATIONSHIP BETWEEN STRESS-RELATED METABOLITES AND DISQUALIFYING PATHOLOGY IN AIR TRAFFIC CONTROL PERSONNEL

I. Introduction.

This laboratory's first study of stress in air traffic controllers was carried out in 1968 at O'Hare Tower. Since that time, 15 other studies have been carried out at towers, centers, TRACON's, and flight service stations (4-10). A total of 237 controllers representing trainees, journeymen, and supervisors have been studied; 189 of those are the subjects of this study--48 were either studied too recently for their data to be available or their urinary data were incomplete.

Sufficient time has elapsed since the first study at O'Hare that some controller subjects have suffered a variety of medical conditions severe enough to require either waiver or retirement. Notations regarding medical conditions requiring either of the above actions are in the controllers' files in the Aeromedical Certification Branch of the Civil Aeromedical Institute. These files were searched for controller subjects who developed medical conditions after they were studied. Thirty-six (19 percent of the total) such controllers were identified who developed pathology after the time of the stress study in which they served as subjects. These controllers showed pathology in one or more of three groups: gastrointestinal, neuropsychiatric, and cardiovascular (Table 1). A further breakdown of the three conditions by region and facility is shown in Table 2.

II. Results.

An index developed in this laboratory (6) readily allows the comparison of excretion values for 17-ketogenic steroids, epinephrine, and norepinephrine. The average of the three individual indices (c_{st}, c_e, and c_{ne}) is the composite stress index (C_s). The individual and composite indices for normal controllers (those without a pathology file) and those with pathological conditions are shown in Table 3. The table shows that for the whole population of controllers, those who developed gastrointestinal pathology had significantly ($p < 0.01$) higher c_{st} than did their normal counterparts at the time they were studied. The index

TABLE 1. Distribution of Diagnoses Among Three Major Disease Categories

Disease Category	Diagnosis	Percentage Occurrence
Gastrointestinal		
	Gastric Ulcer	15.4
	Duodenal Ulcer	15.4
	Peptic Ulcer	15.4
	Gastritis	15.4
	Gall Bladder	7.7
	Other	30.7
Cardiovascular		
	Myocardial Infarction	26.7
	Coronary Insufficiency	6.7
	Hypertension	33.3
	Angina	13.3
	Arteriosclerotic Heart Disease	13.3
	Arrhythmia	6.7
Neuropsychiatric		
	Anxiety Reaction	21.8
	Anxiety Depression	21.8
	"Neuroses"	8.7
	Cluster Headaches	4.3
	Depression	4.3
	Personality Disorder	4.3
	Schizophrenia	8.7
	Anxiety Neuroses	21.8
	Psychosomatic Illness	4.3

TABLE 2. Distribution of the Three Major Disease Categories Among Regions and Facilities

Region	Facility	Gastro-intestinal	Cardio-vascular	Neuro-psychiatric
Southern				
	Opa Locka Tower	0	0	1
	Miami ARTCC	3	8	12
	Atlanta ARTCC	0	1	3
		3	9	16
Southwest				
	Houston Inter-continental Tower	1	1	0
	Fort Worth ARTCC	1	1	3
		2	2	3
Central				
	O'Hare Tower (1968)	4	1	2
Western				
	Los Angeles TRACON	0	0	0
	Oakland TRACON	1	0	0
		1	0	0

TABLE 3. Pathology and Grouped Stress Indices for the Entire Subject Population

	c_{st}	p*	c_e	p*	c_{ne}	p*
Normal	0.67	≤ 0.01	0.60		0.77	
Gastrointestinal	1.12	0.01	0.61	ns**	0.68	ns
Cardiovascular	0.94	ns	0.74	ns	1.25	≤ 0.05
Neuropsychiatric	0.64	ns	0.82	ns	0.85	ns

*p = Level of significance of difference between normal and pathological conditions

**ns = Not significant

Unpaired t-test

for norepinephrine (c_{ne}) was also elevated significantly ($p < 0.05$) over the normals for the cardiovascular pathology group.

When the individual facilities are considered, c_{ne} is significantly ($p < 0.05$) elevated in the cardiovascular pathology group at Miami ARTCC (Table 4). There are no other points of significant difference.

III. Discussion.

This study indicates that high levels of steroid excretion are related to the presence or later development of gastrointestinal disease, the most common "stress related" disease. As shown in Table 1, the principal subcategories of that disease relate to ulceration of the stomach and duodenum. Ulcers have long been known to be related to high levels of endogenous steroids (1,2,11).

At Miami Center, the occurrence of cardiovascular disease (25 percent hypertension, 75 percent coronary artery disease) is significantly related to high levels of norepinephrine excretion. Norepinephrine is the principal catecholamine liberated by the sympathetic nervous system and is, therefore, the main regulator of arteriolar resistance. Norepinephrine has also been shown to have pronounced effects in causing arrhythmias and fatty changes in the hearts of dogs (3).

This study suggests that excretion levels of 17-ketogenic steroids and norepinephrine may be predictive of heart disease, hypertension, and gastrointestinal ulceration. However, because of the small number of controllers in each diagnostic category, the statistics leave much to be desired; the findings reported here are, therefore, tentative, and this report should be viewed as preliminary. The pathology files will be periodically checked in the years to come to see if the statistical validity of these observations changes as more controllers join the list of those with pathology files.

TABLE 4. Pathology and Individual Stress Indices for Various ATC Facilities

ATC Facility	Disease Category	c_{st}	p*	c_e	p*	c_{ne}	p*
O'Hare Tower							
	Normal	1.23		0.74		0.99	
	Gastrointestinal	1.73	ns**	0.71	ns	0.79	ns
	Cardiovascular	2.91	†	1.07	†	1.51	†
	Neuropsychiatric	1.56	ns	0.71	ns	0.73	ns
Opa Locka Tower							
	Normal	0.67		0.74		1.21	
	Gastrointestinal	0.00	†	0.00	†	0.00	†
	Cardiovascular	0.00	†	0.00	†	0.00	†
	Neuropsychiatric	0.17	†	0.63	†	0.42	†
Miami ARTCC							
	Normal	0.59		0.68		0.88	
	Gastrointestinal	0.73	ns	0.42	ns	0.78	ns
	Cardiovascular	0.74	ns	0.69	ns	1.43	0.05
	Neuropsychiatric	0.65	ns	0.84	ns	0.96	ns
Atlanta ARTCC							
	Normal	0.80		0.29		1.38	
	Gastrointestinal	0.00	†	0.00	†	0.00	†
	Cardiovascular	0.34	†	0.53	†	1.25	†
	Neuropsychiatric	0.59	ns	0.52	ns	1.31	ns
Fort Worth ARTCC							
	Normal	0.23		0.54		0.20	
	Gastrointestinal	0.09	†	0.88	†	0.36	†
	Cardiovascular	0.60	†	1.04	†	0.16	†
	Neuropsychiatric	0.24	ns	1.21	ns	0.20	ns

TABLE 4 (Continued)

Facility	Category	c_{st}	p*	c_e	p*	c_{ne}	p*
Houston Intercontinental Tower							
	Normal	1.01		0.40		0.59	
	Gastrointestinal	1.77	†	0.96	†	0.57	†
	Cardiovascular	1.77	†	0.96	†	0.57	†
	Neuropsychiatric	0.00	†	0.00	†	0.00	†
Oakland TRACON							
	Normal	0.37		0.85		0.48	
	Gastrointestinal	0.48	†	0.41	†	0.30	†
	Cardiovascular	0.00	†	0.00	†	0.00	†
	Neuropsychiatric	0.00	†	0.00	†	0.00	†
Los Angeles TRACON							
	Normal	0.63		0.38		0.79	
	Gastrointestinal	0.00	†	0.00	†	0.00	†
	Cardiovascular	0.00	†	0.00	†	0.00	†
	Neuropsychiatric	0.00	†	0.00	†	0.00	†

*p = Level of significance of difference between normals and diseased

**ns = Not significant

† = Number of cases insufficient for statistical treatment

REFERENCES

1. Gray, S. J., J. A. Benson, H. M. Spiro, and R. W. Reifenstein: Effects of ACTH and Cortisone Upon Stomach, GASTROENTEROLOGY, 19:658-673, 1952.

2. Kirsner, J. B., A. P. Klotz, and W. L. Palmer: Unfavorable Course of Gastric Ulcer During Administration of ACTH and Cortisone, GASTROENTEROLOGY, 20:27-29, 1952.

3. Maling, H. M., and Benjamin Highman: Exaggerated Ventricular Arrhythmias and Myocardial Fatty Changes After Large Doses of Norepinephrine and Epinephrine in the Unanesthetized Dog, AM. J. PHYSIOL., 194:590-596, 1958.

4. Melton, C. E., J. M. McKenzie, B. D. Polis, G. E. Funkhouser, and P. F. Iampietro: Physiological Responses in Air Traffic Control Personnel: O'Hare Tower, FAA Office of Aviation Medicine Report No. AM-71-2, 1971.

5. Melton, C. E., J. M. McKenzie, R. C. Smith, B. D. Polis, E. A. Higgins, S. N. Hoffmann, G. E. Funkhouser, and J. T. Saldivar, Jr.: Physiological, Biochemical, and Psychological Responses in Air Traffic Control Personnel: Comparison of the 5-Day and 2-2-1 Shift Rotation Patterns, FAA Office of Aviation Medicine Report No. AM-73-22, 1973.

6. Melton, C. E., J. M. McKenzie, J. T. Saldivar, Jr., and S. M. Hoffmann: Comparison of Opa Locka Tower With Other ATC Facilities by Means of a Biochemical Stress Index, FAA Office of Aviation Medicine Report No. AM-74-11, 1974.

7. Melton, C. E., R. C. Smith, J. M. McKenzie, J. T. Saldivar, Jr., S. M. Hoffmann, and P. R. Fowler: Stress in Air Traffic Controllers: Comparison of Two Air Route Traffic Control Centers on Different Shift Rotation Patterns, FAA Office of Aviation Medicine Report No. AM-75-7, 1975.

8. Melton, C. E., R. C. Smith, J. M. McKenzie, S. M. Hoffmann, and J. T. Saldivar, Jr.: Stress in Air Traffic Controllers: Effects of ARTS-III, AEROSP. MED., 47(9):925-930, 1976.

9. Smith, R. C.: The State-Trait Anxiety Inventory and the Assessment of Stress in Private Pilot Training. Proceedings

of the 80th Annual Convention of the American Psychological Association, 7:64-65, 1972.

10. Smith, R. C., and C. E. Melton: Susceptibility to Anxiety and Shift Difficulty as Determinants of State Anxiety in Air Traffic Controllers, AEROSP. MED., 45:599-601, 1974.

11. Thorn, G. W., D. Jenkins, J. C. Laidlaw, F. C. Goetz, J. F. Dingman, W. L. Arons, D. H. P. Streeten, and B. H. McCracken: Pharmacologic Aspects of Adrenocortical Steroids and ACTH in Man, N. ENGL. J. MED., 248:323-337, 1953.