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16. Abstract

Ten healthy female pilots, 20-49 years old and weighing more than 110 pounds were tested for tolerances to hypoxia orthostatic stress, and physical work at 1 and 3 d after donating about 450 mL of blood on one occasion, and 6 mL (sham control) on a second separate occasion. Testing included consecutive 30-min seated exposures to each of four oxygen-nitrogen mixtures (equal to air breathing at 6,000, 8,000, 10,000 and 12,400 ft of altitude), 5 min of quiet standing, and seated pedal ergometry graded to produce a heart rate of 140 beats per min. At 1 d after blood donation as compared to controls: functional incapacitation occurred in six subjects starting at 10,000 ft altitude; psychomotor performance during hypoxic exposure was decreased; transient orthostatic instability occurred; and, work capacity was decreased. At 3 d after blood donations as compared to controls: functional incapacitation occurred in three subjects at the end of exposure to 10,000 ft altitude; psychomotor performance remained decreased; Orthostatic stability improved; and, physical work capacity remained decreased.

The findings of this study indicate that, in the complete absence of adverse symptoms at ground level, a pilot may return to flying between 1 and 3 d after blood donation with the recommended initial precautions that: cabin altitude be limited to ≤ 6,000 ft (mean sea level); physical activity be minimized immediately before as well as during flight; and +Gz stress exceeding the equivalent of short-duration level turns at 30° of bank angle be avoided. Until complete restoration of the pilot's in-flight physiological tolerances has occurred, the presence of a copilot and on-board availability of supplemental oxygen are also recommended.

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Women air pilots
Blood donors

Donation of organs, tissues, etc.

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LIST OF TABLES

		Page
TABLE I.	Experimental Protocol	16
TABLE II.	STAI Questionnaire (Preceding altitude)	17
TABLE III.	CHb and Hct Data	18
TABLE IV.	Control Measurements Ground Level (1,300 ft MSL)	19
TABLE V.	SBP (torr) (During P&M test at altitude) DBP (torr) (During P&M test at altitude)	20
TABLE VI.	PP (torr) (During P&M test at altitude) AP (torr) (During P&M test at altitude)	21
TABLE VII.	HR (bpm) (During P&M test at altitude) $\dot{V}_E$ (L/min BTPS) (During P&M test at altitude)	22
TABLE VIII.	HbO_2 (% Saturation) (During P&M test at altitude) CaO_2 (mL/dL) (During P&M test at altitude)	23
TABLE IX.	P&M Data Arithmetic Error Score Eye/Hand Coordination Error Score	24
TABLE X.	Orthostatic Testing SBP (torr) DBP (torr)	25
TABLE XI.	Orthostatic Testing PP (torr) AP (torr)	26
TABLE XII.	Orthostatic Testing HR (bpm)	27
TABLE XIII.	Pedal Ergometry Data	28

LIST OF ABBREVIATIONS

BD	Blood donation
THb	Total circulating hemoglobin
BV	Blood volume
G	Gravity
CHb	Hemoglobin concentration
MSL	Mean sea level
U.S.	United States
Hct	Hematocrit
Hb	Hemoglobin
GL	Ground level
SD	Sham donation
OBI	Oklahoma Blood Institute
CAMI	Civil Aeromedical Institute
STAI	State-Trait Anxiety Inventory
ECG	Electrocardiogram
P&M	Psychomotor and Mentation
HbO_2	Oxyhemoglobin saturation
BP	Blood pressure
V_E	Pulmonary ventilation
HR	Heart rate
CaO_2	Arterial oxygen content
W	Watts
bpm	Beats per minute
SBP	Systolic blood pressure
AP	Mean arterial pressure
DBP	Diastolic blood pressure
PP	Pulse pressure
PO_2	Partial pressure of ambient oxygen
COHb	Carboxyhemoglobin
CO	Carbon monoxide
DPG	Diphosphoglycerate
PIC	Pilot in command

AVIATION-RELATED CARDIORESPIRATORY EFFECTS OF BLOOD DONATION IN FEMALE PRIVATE PILOTS

INTRODUCTION

The immediate effects of a typical blood donation (BD) are a decreased total circulating hemoglobin (THb), and a blood volume (BV) reduction of about *450* mL. Because the donor's vulnerability to orthostatic intolerance in a +1G (gravity) environment is increased **(28),** it is logical that vulnerability to a $\geq$ +1Gz stress during in-flight aviation maneuvers should be even greater. Intravascular replenishment of the donated liquid volume **in** about *24-48* hours **(5,24),** which reduces vulnerability to orthostatic intolerance, generates a functional anemia by dilutional reduction of the hemoglobin concentration (CHb) **(8,13).** The CHb remains maximally reduced for about *2-7* d **(10).** Both the hypovolemia and anemia phases subsequent **to BD** are of potential aeromedical concern in general aviation pilots who may encounter transient in-flight exposures to $\geq$ +1Gz, and cabin altitudes up to **12,500** ft *(3,810* m) mean sea level (MSL) while breathing ambient air.

The United States (U.S.) qualification criteria for donating a full unit (about *450* **mL,** nearly one pint) of blood are: minimum body weight of **110** pounds for males or females; a CHb of $\geq$ **13.5** g/dL **or** a hematocrit (Hct) of $\geq$ **41** percent for males; and, a CHb of $\geq$ **12.5** g/dL **or** a Hct of $\geq$ **38** percent for females *(9).* The CHb and BV before donation **(4,6,41),** and the hemoglobin (Hb) regeneration rate after BD **(13)** are smaller in the average U.S. female than in the average U.S. male. **In** *1980,* the average weight of U.S. female pilots was *132.2* pounds and that of **U.S.** male pilots was *178.4* pounds *(26).* Blood volume is positively correlated with body weight **(4,41),** and the possibility of adverse effects of BD increases as the percentage of donated BV increases. Based **on** all of these considerations, this study focused initially **on** female pilots as subjects. The main purpose was to determine how **soon** such female pilots could return to flying after donating about *450* mL of **blood.** Assessment of effects at 1 and *3* d after separate donations of *6* **mL** (sham) of blood **on** one occasion, and about *450* mL **on** a second separate occasion, was based **on** each pilot's measured and subjective responses at ground level **(GL)** to hypoxic gas inhalation equivalent to breathing air at *6,000, 8,000,* **10,000** and *12,400* ft **MSL** of altitude, *5* min of quiet standing, and submaximum pedal ergometry.

METHODS

Subjects. The participants were **10** female pilots, *20-49* years old and prospective **or** full members of the "Ninety-Nines" pilot organization. After each subject underwent a briefing and signed a voluntary consent form, she was medically screened, and then trained for the experimental protocol as outlined in Table **I.** The subject was then scheduled to return for an identical experimental session at **1** and *3* d after either a sham donation (SD) **or** a **BD.**

The means and standard errors of the subjects' ages, heights, and weights were 38.1 ±2.6 years, 65.8 ±0.6 inches, and 137.5 ±6.4 pounds, respectively. They had logged an average of 358 flight hours and 6 years of flying. Medical certification was Class II for two of them and Class III for the remaining eight. Four subjects had previously donated blood, and three were currently smokers.

Protocol and Measured Variables. After successful training, each subject was scheduled to return on a subsequent day for either an SD or BD. The BD's were done at the Oklahoma Blood Institute (OBI) in Oklahoma City. Each subject consented to be transported as a passenger to and from the OBI on the day of BD. The blood was drawn at *0900.* The OBI provided concomitant measurements of CHb and Hct using Coulter methods (27); donated BV was calculated from the measured weight (in grams) of the donated blood and an assumed density of 1.053 g/mL (27). The SD's and all other experimental sessions were conducted at the Civil Aeromedical Institute (CAMI) in Oklahoma City. To minimize CHb and Hct variability related to postural and activity changes (17), all blood samples were drawn after a minimum of 20 min of seated rest.

In the two experiments, each subject underwent an assessment protocol at 1 and 3 d after the SD or the BD. To preclude order effects, half of the subjects underwent BD in the first experiment, and the remaining half underwent it in the second experiment. The pooled data were statistically compared according to Student's paired t-test (35) on the basis of SD versus BD at 1 and 3 d after donation. Statistical significance was based on a probability value of $p \leq 0.05$ (35). To assure complete restoration of the Hb lost in the BD (26), each subject's BD and SD were separated by a minimum of 8 weeks.

The postdonation assessment protocol is outlined in Table I. For the 1 d assessment, each subject ate breakfast prior to arriving at 0830. The subject initially provided information regarding the first 16 hours (up to bedtime) after SD or BD. This consisted of her reporting the presence/absence of unusual degrees of mental fatigue, physical fatigue, and orthostatic intolerance; whether or not she thought that her piloting ability had been compromised to an unsafe degree; and, whether or not she would have piloted an aircraft during this time and, if so, would she have unusually limited her altitude, flight duration, +Gz maneuvers, and/or flown without a copilot. Next, she was asked for the same information pertaining to the morning of 1 d after SD or BD.

The subject's body temperature and general health were checked. She filled out the State-Trait Anxiety Inventory (STAI) questionnaire (37) to assess her "right now" anxiety state. A 6 mL venous blood sample was then drawn for measurement of CHb and Hct using Coulter and microhematocrit centrifuge techniques, respectively (27). The subject donned a surgical scrub suit, and electrodes were attached to her chest for recording a CM_5 single-lead electrocardiogram (ECG) (3). After the subject voided urine, her weight was measured. She was seated in a comfortable chair and given a writing board. Next, she took the combined psychomotor and mentation (P&M) test as a learning refresher. This test consisted of 20 pages of simple addition and subtraction problems to be answered true or false by using a checkmark in eaeh appropriate answer block. The arithmetic score equaled the product of the number of incorrect answers and the time (min) for test completion. The eye/hand

coordination score equaled the product of block boundary violations and time (min) for test completion.

After again voiding urine for comfort's sake, the subject was reseated for the remaining 3 h of testing. At this time, an oximeter sensor was placed on the subject's right ear for measuring oxyhemoglobin saturation (HbO_2) (25,321, a blood pressure (BP) cuff was placed on her right arm, and the ECG cable connected to its recorder. Eight minutes of control measurements were obtained at this time. An oronasal mask was then donned by the subject and she began consecutive 30-min exposures to separate oxygen-nitrogen mixtures equal to air breathing at 6,000, 8,000, 10,000 and 12,400 ft altitude. The subject took one timed P&M test starting at the 10th min of each altitude. Mean values of pulmonary ventilation ($\dot{V}_E$), HbO_2, and heart rate (HR) were obtained from continuous recordings during the entire P&M test. The $\dot{V}_E$ was measured by a flow transducer in the inspiratory circuit. The BP measurement representing each P&M test period was obtained at the completion of the test. The mean value for arterial oxygen content (CaO_2) during each P&M test was obtained by multiplying the concomitant mean HbO_2 by CHb x 1.34 (31).

Before and after each P&M test, the subject answered a checklist of questions regarding the possible presence and degree of adverse symptoms.

During training, each subject had been taught simple hand signals to facilitate communication while wearing the mask. Each subject had the unconditional option of terminating hypoxic exposure by lifting the mask off of her face. A staff physician and emergency resuscitation equipment were available on a standby basis.

After completion of simulated altitude exposure, and removal of the subject's mask and HbO_2 sensor, suitable recovery and additional control measurements preceded the orthostatic test of 5 min of quiet standing. After this test and additional control measurements, the subject redonned the mask (for measuring $\dot{V}_E$), and underwent pedal ergometry at a starting load of 30 watts (W) for 1 min. The load was increased 5 W per min up to 75 W, which was sustained for 5 min. The test was terminated at this maximum load or earlier, if and when an HR of 140 beats per min (bpm) was reached, or limiting symptoms occurred. The ECG, HR, and BP were measured during both the quiet standing and ergometry tests. After monitored recovery, the subject redonned her street clothes and underwent a comprehensive interview to assess all encountered subjective symptoms that might be potentially adverse to flight safety. She was also asked to evaluate the presence and degree of any decrements in her piloting safety associated with the SD or BD. The subject was then scheduled to return 2 d later for an identical experimental session.

Temperature and relative humidity ranges in the experimental room during the whole study were 22.0-24.5° and 43.0-50.0 percent, respectively.

Because appreciable reductions in CHb and Hct may persist for more than 3 d after BD (33,39), each subject was asked to return 7 d after BD for measurement of CHb and Hct. Eight subjects complied with this request. Also, each subject was asked to report all piloting done within 3 weeks after BD. Data of particular interest were altitudes, flight durations; >+1Gz maneuvers, and the presence of any symptoms which could compromise safety.

RESULTS

As calculated from measured height and weight data (4), the subjects' mean predonation BV (and standard error) was 3,742.8 ±124.4 mL. The mean volume of donated blood was 460.1±3.4 mL. The BD's constituted a mean of 12.4 ±0.4 percent of the predonation BV's.

STAI data, which assessed mood state preceding altitude exposure, are summarized in Table II. Only the depression–dejection mood state showed a statistically significant mean increase 1 d after BD as compared to SD. No significant differences were present at 3 d after BD.

Table III summarizes the CHb and Hct data. The CHb and Hct mean decrements at 1 and 3 d, and at 7 d after BD were statistically significant, and those at 7 d were less than the corresponding values at 3d.

Table IV summarizes initial control cardiovascular data obtained at GL (1,300 ft MSL). Although the mean values of these five variables at 1 and 3 d after BD were lower than the corresponding values after SD, only those of the systolic BP (SBP) were statistically significant.

Simulated Altitude Exposure. One day after BD, six subjects became functionally incapacitated during altitude exposure. One incapacitation occurred at the start and one at the end of exposure to 10,000 ft altitude, and the remaining four during the first 10 min at 12,400 ft. Three days after BD, three of these same six subjects became incapacitated during altitude exposure. One incapacitation occurred at the end of exposure to 10,000 ft altitude, and the remaining two at 12,400 ft. For this study, functional incapacitation was defined as definite hypoxia symptoms approaching loss of consciousness. In the 1 and 3 d assessments after SD, hypoxia symptoms were absent in seven of the subjects. The remaining three subjects showed minor symptoms, and these only at 12,400 ft. Of these three, two were among those who became incapacitated during the experimental altitude exposures after BD.

Tables V-VIII summarize the cardiovascular data obtained during the P&M tests of the first three altitudes. The corresponding data for 12,400 ft were not statistically analyzed because sufficient pairs of data were unavailable due to preceding incapacitations at that altitude. As these tables show, statistically significant mean decrements occurred in SBP, mean arterial pressure (AP), $\dot{V}_E$, and CaO_2 as compared to the corresponding data after SD. Excepting Ca_{O2}, 8,000 ft appeared to be the general altitude threshold for significant cardiorespiratory decrements after BD. This altitude threshold for significant cardiorespiratory decrements was generally correlated with the concomitant onset of hypoxia symptoms after BD.

Symptoms During Simulated Altitude Exposure. One day after BD, three subjects reported drowsiness onset at the end of exposure to 6,000 ft altitude. At 8,000 ft all subjects showed drowsiness along with varying degrees of yawning, stretching, and restlessness. During the P&M test at this altitude, visual focusing difficulty began in two subjects, and mental concentration began to deteriorate in nine subjects. At 10,000 ft, drowsiness intensified, and began to include short periods of eyelid droopiness/closing in all

subjects; some head drooping/bobbing occurred in five subjects, and headache onset in one subject; visual difficulty commenced in three others. The two subjects who became incapacitated at 10,000 ft experienced progressive presyncopal visual symptoms of blurring, graying, and tunneling. At 12,400 ft, drowsiness and deterioration of mental concentration showed further intensification in the remaining eight subjects. Of the four subjects who became incapacitated at this altitude, one experienced the progressive visual symptoms of presyncope, and the remaining three approached loss of consciousness via an overpowering sleepiness. Despite the presence of hypoxia symptoms in the remaining four subjects, they were able to complete the 30-min period at 12,400 ft. Although these four subjects were not incapacitated, they reported retrospectively that their estimated safety margins as pilots had been definitely reduced. They reported that, in the event of such symptoms in flight, supplemental oxygen and/or decreased altitude would have been used until all the symptoms disappeared.

Three days after BD, symptom onset did not occur until 8,000 ft. At this altitude, drowsiness along with restlessness and yawning started in six subjects, a decrease in mental concentration commenced in five subjects, and visual difficulty began in one subject. At 10,000 ft, drowsiness was present in nine subjects, with eyelid drooping/closing and head drooping starting in five of them. Visual difficulty was present in four subjects, and decreased mental concentration was present in all subjects and intensifying at individual rates. One subject became incapacitated at this altitude due to overpowering sleepiness. At 12,400 ft, intensified drowsiness and decreased mental concentration were present in all subjects, and visual difficulty was present in five of them. The two subjects who became incapacitated were unable to withstand the intense sleepiness which was approaching loss of consciousness. The remaining seven subjects reported retrospectively that, although their symptoms felt less severe than at the same altitude 1 d after BD, they were severe enough to cause some reduction in estimated margins of piloting safety.

P&M Performance During Simulated Altitude Exposure. Table IX summarizes the P&M mean scores of the first three altitudes. The corresponding data for 12,400 ft were not statistically analyzed because of insufficient data due to the preceding incapacitations. As indicated by the mean scores in Table IX, both the arithmetic and eye/hand coordination performances at each altitude were decreased at 1 and 3 d after BD as compared to 1 and 3 d after SD. However, only one of the mean score differences for eye/hand coordination errors was statistically significant.

Orthostatic Tolerance. Tables X-XI1 summarize the cardiovascular data from the control period, and the ensuing 5 min of quiet standing. During the control period, the mean values of SBP, diastolic BP (DBP), pulse pressure (PP), and AP at 1 and 3 d after BD were lower than the corresponding values after SD. However, only the SBP decrement at 1 d after BD was statistically significant compared to the corresponding value after SD. During the first and fourth min of quiet standing, the mean values of the four BP variables were lower at 1 and 3 d after BD (except PP at 3 d) than the corresponding mean values after SD. However, only the decrements in the first-min mean values of SBP and AP at 1 d after BD were statistically significant. Although the mean HR's during quiet standing were higher at 1 and 3 d after BD than at 1 and 3 d after SD, the differences at 3 d were less than at 1 d. None of the mean HR differences between SD's and BD's were statistically significant.

Symptoms During Orthostatic Testing. One day after BD, four subjects reported transient symptoms during the first 10 s of quiet standing. Shaky unsteadiness was the main symptom in two subjects, lightheadedness in the third one, and a lightheaded flushed feeling in the fourth. One subject, devoid of symptoms during the standing test, experienced transient severe lightheadedness upon standing after 8 min of seated recovery from pedal ergometry.

Three days after BD, residual unsteadiness occurred in the same two subjects upon standing, but of much less severity and duration than at 1 d after BD. Symptoms were absent from all subjects during the quiet standing test at 1 and 3 d after SD.

Pedal Ergometry. The pedal ergometry data are summarized in Table XIII. The mean values for total pedaling work (W x min) achieved at 1 and 3 d after BD were much less than the corresponding mean values achieved at the same HR 1 and 3 d after SD. Both the 1 and 3 d work decrements were statistically significant. This finding is consistent with that of Balke et al. (1). Although the mean values for $\dot{V}_E$ and HR during isoload pedaling at 1 and 3 d after BD (Table XIII) were greater than the corresponding values measured at the same total workload at 1 and 3 d after SD, only the HR increments were statistically significant. Valid BP measurements were not attainable during pedal ergometry because high noise/signal ratios obliterated the Korotkov sounds.

Symptoms During Pedal Ergometry. Although the total pedaling work achieved at the same HR by the subjects at 1 d after BD was significantly less than at 1 d after SD, fatigue symptoms in six of the subjects were greater during ergometry after BD than after SD. These six subjects reported leaden heaviness in their legs during pedaling, deeper and harder breathing with shortness of breath, and intense physical fatigue nearing its subjective limit at the end of the test. Symptoms receded slowly during recovery.

Three days after BD, these same six subjects reported similar and less intense symptoms than at 1 d after BD, but the symptoms were still greater than those during ergometry at 1 and 3 d after SD.

SUPPLEMENTAL SUBJECTIVE REPORTS

Symptoms Within 16 h After BD. Symptoms relatable to BD were those which were present after BD, but not after SD. One subject, who had no adverse symptoms during BD or upon standing immediately thereafter, almost fainted 15 min after leaving the Blood Donation Center. She experienced sudden severe lightheadedness upon quiet standing immediately after running a very short distance from her car into a post office. She immediately squatted (to reduce hydrostatic height), and remained thus until the symptoms disappeared. She abandoned her errand and returned cautiously to the car for additional seated recovery.

During the first 16 h after BD, three subjects experienced considerable sluggishness and fatigue in mentation. Two of these same three subjects plus

three others reported unusual degrees of physical fatigue described as slowness, inertia, leaden heaviness, and lassitude. Both mental and physical fatigue were still present at bedtime. Repeated lightheadedness (upon standing) which occurred in three subjects, tapered off by bedtime. Based on self-appraisal of symptoms, two subjects would not have flown at this time because they felt unsafe as pilots, two would have flown only if accompanied by a copilot, one was indecisive, and the remaining five felt that they could have flown safely as solo pilots, None of the subjects actually flew during this period.

Symptoms at 1d After BD. Preexperimentally, slight residual physical fatigue and inertia were reported by two subjects, residual mental sluggishness by a third subject, and lightheadedness upon first arising by a fourth subject. One of these four expressed reservations about her safety to fly at this time, but would have done so in the next 4 h if accompanied by a copilot. The remaining nine subjects felt that their current mental and physical conditions were fully compatible with safe solo flight in the next 4 h.

Symptoms at 3 d After BD. Preexperimentally, all subjects reported the absence of adverse mental symptoms and lightheadedness. Two subjects reported slight residual physical sluggishness. These two subjects said that they would have flown in the next 4 h, but only in the presence of a copilot and at less than 8,000 ft altitude. The remaining eight subjects judged their mental and physical conditions to be fully compatible with safe solo flight in the ensuing 4 h.

Anecdotal In-Flight Information. Five subjects did some flying with copilots within 3 weeks after BD. Pertinent information from these flights is summarized in Appendix A.

DISCUSSION

Altitude Tolerance 1 d After BD. One day after BD, hypoxia-related symptoms started in three subjects at 6,000 ft. The incapacitation of two subjects occurred at 10,000 ft and four more at 12,400 ft. Although the remaining four subjects were not incapacitated, they were definitely impaired by severe drowsiness and decreased mental concentration. Although statistical significance was mostly absent in the P&M data (Table IX), they uniformly reflected mean decreases in psychomotor function at all altitudes. The altitude threshold for statistically significant decrements in SBP, AP and $\dot{V}_E$ (Tables V-VII) coincided with definite establishment of hypoxia symptoms in all 10 subjects. The most prevalent major symptoms were drowsiness and decreased mental concentration. Although some subjects tried to partially ascribe their hypoxic drowsiness to boredom, all readily admitted that all adverse symptoms, including drowsiness, rapidly disappeared after removal of the mask. In all cases, symptom disappearance paralleled the rise of the HbO_2 back to the higher GL values. This pattern of drowsiness was absent from all simulated altitude exposures after SD. Without prior BD, drowsiness is known to occur commonly as a symptom of altitude hypoxia (21,29,40), but it usually commences at higher altitudes than those simulated in this study.

The mean values of CaO_2 (Table VIII) at each altitude reflected the decreased level of arterial oxygenation at 1 d after BD as compared to 1 d after SD. As reflected in Table III, the mean CHb was nearing its minimum value at this time. The CaO_2 reductions are consistent with the increased vulnerability to hypoxia at increasing altitudes.

When drowsiness and decreased mental concentration reached appreciable levels during altitude exposure after BD, the subjects reported that these symptoms increased and decreased in an oscillating manner. From then onward, it was consistently observed that increasing HR and drowsiness symptoms and decreasing mental concentration were preceded by decreasing ventilation and HbO_2, and a reversal of this pattern was preceded by increasing ventilation and HbO_2. This oscillatory pattern was present in all subjects after BD at the threshold altitude of 8,000 ft. The amplitude and frequency of oscillation became greatest in the six subjects who subsequently became incapacitated.

Because hypoxia effects were absent during simulated altitude exposure after SD, the effects observed after BD are logically relatable to a combined effect of reduced CHb and residual hypovolemia. Assuming that the initially diminished THb remains constant at 1 d after BD (36), then the predonation/postdonation ratios of CHb and Hct can provide a percentage estimate of BV restoration. Calculated in this manner, mean BV 1 d after BD approximated 95 to 97 percent of predonation values. This estimate is consistent with those of other studies (5,24). Therefore, the hypoxia effects observed at 1 d after BD were mainly relatable to the decreased CHb.

The four subjects who were impaired but not incapacitated during altitude exposure after BD manifested the highest predonation CHb values. The two highest values (14.8 and 15.9 g/dL) were those of the two heavy cigarette smokers. The nonincapacitation of these two subjects at 12,400 ft would not be anticipated if the usual elevated carboxyhemoglobin (COHb) levels found in heavy smokers (38) were present, but upon cessation of smoking, the half-life washout of carbon monoxide (CO) from the blood's COHb is about 3-5 h (22). Smoking by each subject was forbidden from 0830 until completion of all testing. Altitude exposure usually occurred between 1030-1230. Therefore, any dissociation and washout of CO from the blood's COHb up to 1230 must have increased the amount of Hb available for additional oxygenation and support of altitude tolerance. Quantitation of this effect in these two smokers was not possible, because COHb was not measured at 0830 and 1230.

The unsteadiness or lightheadedness in four subjects at the onset of the quiet standing test 1 d after BD reflected a residual effect of hypovolemia. Additional plasma volume losses probably occurred during the 2-3 h of sedentary testing preceding the standing test (23).

If blood loss is not rapid and amounts to less than 20 percent of the initial BV, compensatory reflex increases in cardiac contractility, HR, and arterial vasoconstriction (7,16) usually suffice to sustain useful consciousness under upright resting conditions (11,14). However, as evidenced by the near-syncope incident of one subject about 15 min after BD, the "opening up" of the circulation by a short bout of exercise can overwhelm the ability of the compensatory cardiovascular reflexes to maintain cerebral perfusion around the time of maximum hypovolemia. Even without prior BD, fainting due to post-exertional blood pooling in the standing position can occur (12, 34).

After BD, because volume restoration dilutes the CHb, some reflex cerebral and coronary vasodilation is necessary to maintain cerebral and myocardial oxygenation (7). However, any such vasodilation must be counterbalanced by peripheral arterial vasoconstriction in order to maintain the hydrostatic pressure required for cerebral perfusion (7). Although this integrated control is readily achieved at GL under resting normoxic conditions, the superimposition of altitude hypoxia can impair and overwhelm this delicately balanced compensatory mechanism (18,19) and, in some instances, do it suddenly (2). The incapacitations which occurred during altitude exposure 1 d after BD were most likely precipitated by the inadequacy of this compensatory mechanism to maintain cerebral perfusion. The preceding small but significant mean decrement in SBP and AP (Tables V and VII) were consistent indications of this decompensation. Reflex compensatory increases in HR and $\dot{V}_E$ (Table VII) did not occur. It is possible that the internal systems ordinarily responsible for hypoxically stimulated increases in HR and $\dot{V}_E$ were depressed at this time. However, no direct evidence was obtained in this study to support or deny this possibility. Therefore, the combination of reduced CHb and residual hypovolemia definitely compromised altitude tolerance starting at 8,000 ft.

Altitude Tolerance 3 d After BD. Three days after BD, hypoxia symptoms started in all subjects during the 8,000 ft altitude exposure. By 12,400 ft, three subjects had become incapacitated, and the remaining seven were impaired but not incapacitated. Statistically significant decrements in SBP and CaO_2 (Table V and VIII) persisted at 3d after BD.

The group's general improvement in altitude tolerance 3 d after BD appears paradoxical to the further decreases in CHb and Hct (Table III), and the persistent decrease in $\dot{V}_E$ (Table VII). However, because erythropoiesis is probably starting to increase 3 d after BD (39), the decreased CHb could have reflected a plasma volume increase beyond its predonation level (30). An increased THb along with a slight hypervolemia could have increased cerebral oxygenation and improved hydrostatic protection of cerebral perfusion during altitude exposure. Although not statistically significant, the slight but consistent increase in HR at 3 d after BD as compared to SD (Table VII) could have helped to increase cerebral perfusion. In addition, an increased intraerythrocytic 2,3-diphosphoglycerate (DPG) is capable of enhancing tissue oxygenation by shifting the oxyhemoglobin dissociation curve to the right (5). The degree of these possible effects is conjectural. Although altitude tolerance had generally improved 3 d after BD, altitude tolerance was still impaired starting about halfway through exposure to the 8,000 ft altitude.

Altitude Tolerance 7 d After BD. The mean CHb and Hct decrements at 7 d were less than at 3 d after BD. At 7 d after BD, one can conservatively assume that normovolemia is present, and that appreciable increases in erythropoiesis (30) and 2,3-DPG (5) have occurred. The anecdotal flight data (Appendix A) suggest that altitude tolerance continued to improve at 7 d after BD. Whether or not altitude tolerance had completely returned to predonation levels remains an open question.

Predicted Versus Actual Performance at Simulated Altitude. One and three days after BD, a total of three subjects predicted that they would be unsafe pilots above 8,000 ft, because of residual presence of adverse symptoms at GL. These predictions proved to be valid, for these subjects were among

those who became incapacitated during altitude exposure. Therefore, after BD, if mental and/or physical symptoms are residually present at GL, these effects will most probably be dangerously accentuated in the donor/pilot at some altitude of ≥10,000 ft while breathing ambient air.

Conversely, in the rest of the subjects, the absence of residual symptoms at GL was not a valid predictor of adequacy of altitude tolerance. Prior to altitude testing at 1 and 3 d after BD, these subjects predicted that they could fly safely as solo pilots. During the subsequent altitude testing, all of them became impaired or incapacitated. Retrospectively, all of them concurred that their estimated flight safety margins had been significantly reduced.

Although the depression-dejection mean mood score was significantly increased at 1 d after BD, the individual scores were very poor predictors of subsequent adequate/inadequate altitude tolerance.

Currently, it is not apparent what GL self-test the donor pilot could apply in order to determine her physiological readiness to return to flying. Because the pedal ergometry data (Table XIII) showed that a significant decrement in work capacity remained at 3 d after BD, it is possible that a preflight exercise test self-imposed by the donor/pilot might provide useful subjective sypmtomatic information. Since the CaO_2 data (Table VIII) still showed significant decrements at 3 d, it is possible that restoration of full altitude tolerance parallels the return of CHb towards its predonation level. However, if altitude tolerance remains predictively uncertain, the donor/pilot (and especially the heavy smoker) should be fully prepared to use supplemental oxygen at lower than usual altitudes. Heistad et al. (18) have shown that the hypotensive effects of altitude and hypovolemia combined can be prevented or reversed by supplemental oxygen.

Orthostatic Tolerance 1 d After BD. After BD, the occurrence of adverse symptoms and/or cardiovascular decrements upon quiet standing must logically be construed as an increased risk of intolerance to >+1Gz loads incurred in flight. At 1 d after BD, the transient symptoms and significant SBP and AP decrements (Tables X and XI) at 1 min of quiet standing reflect this increased +Gz vulnerability. The severe lightheadedness in the one subject upon standing after recovery from pedal ergometry indicates an even greater +Gz vulnerability under vasodilated conditions. Although the donors' BV's at 1 d after BD were probably nearing repletion, the 2-3 h of sedentary testing which preceded the standing test could have caused further dependent extravasation losses of plasma volume (22). This type of +Gz vulnerability should increase as a function of flight duration. Flights of 2-3 h duration are fairly common.

As anecdotally reported in Appendix B, one "Ninety-Nines" member (not in this study) piloted a flight 1 d after BD. Her flight included a symptom-free short-duration turn at a 30° bank angle (about +1.2Gz).

Orthostatic Tolerance 3 d After BD. The improvement in the subjects orthostatic tolerance (standing test) at 3 d after BD was consistent with the calculated estimate that total volume repletion had occurred. This is consistent with the previous findings of Green et al. (15). Anecdotal information (Appendix A) indicated that, from 2 d after BD and onward, several

subjects executed prolonged in-flight turns at a 30° bank angle without adverse symptoms. One subject reported that, at 9 d after BD, transient lightheadedness occurred at the start of her execution of 7 20° right and left turns at a 45° bank angle. Therefore, at 3 d after BD, +Gz tolerance had probably improved enough to include (symptom-free) in-flight turns at bank angles of >30° but <45° (about +1.4Gz).

Physical Fatigue Tolerance at 1 and 3 d After BD. Since the estimated mean BV was nearing repletion at 1 d after BD, and was fully repleted at 3 d after BD, the significant decrements in mean total pedaling work (Table XIII) were probably mainly related to the concomitant decreases in mean CHb (Table III). This is consistent with the CaO_2 data in Table VIII. The work decrements shown in Table XIII are consistent with those reported by Woodson et al. (42) in subjects with isovolemic anemia. The increase in the arteriovenous oxygen difference, which usually accompanies an increasing physical workload, was obviously limited by the already lowered preergometry CaO_2. Therefore, because cumulative fatigue could adversely affect psychomotor performance and altitude tolerance, prior workloads should be avoided if the donor has to pilot an aircraft 1-3 d after BD. If the donor/pilot has rested prior to flight, but incurs an appreciable mental and/or physical workload during flight, then use of supplemental oxygen may be beneficial.

Performance Decrement Prior to 1 d After BD. The presence of adverse symptoms at GL 1 and 3 d after BD was a consistent predictor of subsequent altitude intolerance. Despite general curtailment of physical activity by all the subjects during the first 16 h after BD, six of them experienced considerable degrees of mental, physical, and/or orthostatic adverse symptoms. Restoration of the vascular liquid volume at 8 h after BD can be as variable as 25 to 75 percent (5,11,20). The occurrence of adverse altitude and orthostatic reactions at 1 d after BD, in spite of the near repletion of BV, logically suggests that, up to 8 h after BD, such adverse reactions should be greater in number and degree. Therefore, piloting an aircraft within 8 h after BD, in the prior presence of adverse symptoms at GL, is strongly contraindicated. The presence of such symptoms up to 16 h after BD should continue to contraindicate piloting by the donor. Similar to 1 d after BD, the complete absence of adverse symptoms at GL up to 16 h after BD cannot predictively guarantee adequate altitude tolerance in flight.

CONCLUSIONS

Compromise of physiological functions starts immediately after BD of about 450 mL of blood. The initial concern is hypovolemia, which is manifested primarily as an increased vulnerability to orthostatic (+Gz) intolerance. This initial vulnerability is accentuated if the circulation is "opened up" by prior physical activity. As the liquid volume is restored, vulnerability shifts away from orthostatic intolerance towards all oxygenation functions which are vulnerable to acute decreases in CHb. This vulnerability reaches its peak at full restoration of BV when the maximum dilutional reduction of CHb has occurred. From that time onward, as erythropoiesis increases the CHb towards it predonation level, the remaining vulnerability recedes.

Up to 16 h after BD, the presence of appreciable mental and/or physical adverse symptoms at GL contraindicates piloting by the donor. Conversely, the complete absence of adverse symptoms at GL up to 16 h after BD cannot guarantee adequate altitude tolerance by the donor.

Between 1 and 3 d after BD, the residual presence of adverse mental and/or physical symptoms at GL remains a contraindication to piloting by the donor. However, in the complete absence of adverse symptoms at GL, a pilot may return to flying between 1 and 3 d after blood donation with the recommended initial precautions that: cabin altitude be limited to $\leq$ 6,000 ft (mean sea level); physical activity be minimized immediately before as well as during flight; and +Gz stress exceeding the equivalent of short-duration level turns at 30° of bank angle be avoided. Until complete restoration of the pilot's in-flight physiological tolerances has occurred, the presence of a copilot and on-board availability of supplemental oxygen are also recommended.

Because the patterns and rates of recovery after BD manifest large individual degrees of variability, each donor should continue to use the recommended precautionary measures until all adverse residual symptoms both at GL and at altitudes up to 12,500 ft have disappeared. The disappearance of in-flight symptoms should parallel the rebound increase in CHb, which usually begins 3-7 d after BD.

Because males generally have greater predonation BVs and CHb's than females, both the maximum degree of adverse symptoms after BD and the minimum time for adequate recovery should be less in the former than in the latter. However, each male donor/pilot should also use the same recommended initial precautions when returning to flying, and decrease the precautionary measures in accordance with the disappearance rate of his individual adverse symptoms.

Anecdotal Flight Information. One subject flew as a pilot in command (PIC) 19 d after BD. She flew at 3,500 ft MSL for 45 min without adverse symptoms.

One subject flew at 3,500 ft for 45 min as PIC 7 d after BD. During flight, she executed two right and two left 360° turns at a 30° bank angle without adverse symptoms.

One subject flew at 8,500 ft for 75 min as copilot 11 d after BD. A headache developed after 20 min at that altitude, lasted for the rest of the flight, and disappeared spontaneously within 15 min after landing. She reported that this type of headache and its total pattern had never happened to her on any other flight. She flew the 75-min return flight as PIC on the next day at 5,500 ft without adverse symptoms.

One subject flew three separate times as PIC within 9 d after BD. Her first flight on the fourth day was at 5,500 ft for 50 min, and she incurred no adverse symptoms. Her second flight on the sixth day was flown at 4,500 ft for 50 min without adverse symptoms. In this flight, she executed a short-duration 30° bank after takeoff. Her third flight on the ninth day was flown with an instructor pilot at 4,000 ft for 45 min. In this flight she executed one right and one left 720° turn at a 45° bank angle. She reported that transient lightheadedness occurred at the start of each turn and disappeared in about 5 s as each turn was sustained. She reported that in all her piloting preceding BD she had never experienced lightheadedness at the start of any turn at a 45° bank angle.

The fifth subject flew with her husband on three separate occasions within 6 d after BD. Her first flight, a round trip between Oklahoma City and Phoenix, Arizona, took place between 45 and 60 h after BD. After a morning takeoff by her husband, she took over as PIC for the 3-h leg to Albuquerque, New Mexico, at an altitude of 10,000 ft. At this altitude, she experienced some visual focusing difficulty and lightheadedness, which was relieved by intermittent use of supplemental oxygen. During descent for landing at Albuquerque, these symptoms disappeared. On the 2-h leg to Phoenix, she flew as copilot. Her lightheadedness and vision symptoms reappeared at about 11,000 ft during climbout. Starting at 12,000 ft, she reinstituted intermittent use of oxygen for the remainder of the flight. Her symptoms were relieved during oxygen use, and disappeared during descent for landing at Phoenix. The return flight started at 1700, and was flown nonstop to Oklahoma City. After climbout and leveling off at 12,000 ft, she took over as PIC. Shortly thereafter, when hypoxia symptoms began and intensified to a noticeable degree, she started intermittent use of oxygen. Her symptoms of lightheadedness, instrument disorientation, and difficulty with maintaining visual concentration came and went in an oscillating fashion. Her vision was clear but, during instrument scanning, individual gauges sometimes appeared to be "swirling." Although this pattern of symptoms persisted all the way to Albuquerque, she did not consider the maximum symptom level to be severe. Each time she used oxygen, the symptoms abated. As she neared Albuquerque, temporarily off of oxygen, she experienced a frightening rapid onset and intensification of visual blurring

that transitioned into graying and tunneling. Her immediate use of oxygen reversed these symptoms. She reduced altitude to 11,000 ft, and shortly thereafter to 9,000 ft for the rest of the flight into Oklahoma City. All symptoms disappeared at 9,000 ft, and she subsequently made an uneventful night landing at Oklahoma City. During the many times that she had made this round-trip flight, she had never experienced hypoxia symptoms.

Four days after BD, this subject copiloted a 4.5-h flight to Corpus Christi, Texas. Flight altitudes were 6,000 ft for 1.5 h and 10,000 ft for 3 h. Six days after BD, she copiloted the return flight from Corpus Christi to San Antonio at 4,500 ft, and piloted the remaining 3-h leg to Oklahoma City at 9,000 ft. In both flights she experienced no hypoxia symptoms.

Anecdotal Flight Information. One "Ninety-Nines" pilot (not in this study) reported flying 1 d after BD. Her CHb prior to BD was 15.1 g/dL, and her donated BV was estimated at 10.3 percent of her predonation BV. She flew as PIC for 1.5 h at an altitude of 4,500 ft. She executed one short-duration turn at a 30° bank angle. No adverse symptoms occurred during this flight.

TABLE I.

Experimental Protocol

Time (min)	Activity
0 (0830)	Subject arrival
0–90	Preexperimental interview
	Health check
	STAI questionnaire
	Venous blood sample
	Body weight
	Subject instrumentation
	P&M refresher test
90-100	Prealtitude control measurements
100	Start of altitude period
100-130	6,000 ft altitude expsaure
	P&M test #1
130-160	8,000 ft altitude exposure
	P&M test #2
160-190	10,000 ft altitude exposure
	P&M test #3
190-220	12,400 ft altitude exposure
	P&M test #4
220	End of altitude period
220-230	Recovery period
230	Start of orthostatic test period
230-238	Seated control measurements
238–243	Quiet standing period
243-250	Seated recovery period
250	Start of pedal ergometry period
250-255	Seated control measurements
255-269	Pedal ergometry
269–279	Monitored recovery
280–	Postexperimental interview

STAI = State-trait anxiety inventory
P&M = Psychomotor and mentation

TABLE 11.

STAI Questionnaire
(Preceding altitude)

		SD + 1d	BD + 1d	SD + 3d	BD + 3d
A	$\bar{X}$	2.0	2.1	2.0	**1.9**
	SE	0.4	0.7	0.5	0.5
B	$\bar{X}$	0.1	1.2*	**0.2**	0.6
	SE	0.1	*0.4*	**0.1**	0.3
C	$\bar{X}$	0.2	0.2	0.2	0
	SE	0.1	0.1	0.1	0
D	$\bar{X}$	21.0	22.7	20.8	**20.1**
	SE	1.6	1.7	2.2	**1.9**
E	$\bar{X}$	1.4	**1.0**	**0.9**	*2.4*
	SE	0.7	**0.7**	**0.7**	0.7
F	$\bar{X}$	1.9	2.3	1.9	**1.8**
	SE	0.4	*0.4*	0.3	**0.3**

$\bar{X}$ = Mean. SE = Standard error of the mean.
SD = Sham donation. BD = Blood donation.
A = Tension-anxiety. B = Depression-dejection.
C = Anger-hostility. D = Vigor.
E = Fatigue. F = Confusion-bewilderment.
* = $p \leq 0.05$
All symbols have been defined previously in Table I or the text.

TABLE 111.

CHb and Hct Data

		SD	Percent of SD Value + 1d	Percent of SD Value + 3d	BD	Percent of BD Value + 1d	Percent of BD Value + 3d	Percent of BD Value + 7d
CHb	$\bar{X}$	13.8	100.6	99.7	13.8	90.9*	89.8*	91.8*
g/dL	SE	0.3	0.5	1.4	0.3	1.2	1.3	1.0
Hct	$\bar{X}$	41.7	100.5	100.1	41.8	91.7*	89.1*	91.4*
Percent	SE	0.7	0.6	1.5	0.8	0.7	0.9	1.0

CHb = Hemoglobin concentration (g/dL of whole blood).
Hct = Hematocrit (mL of erythrocytes/dL of whole blood).
The means and standard errors for CHb and Hct at BD + 7 d are based on a paired sample n of 8.
All other symbols have been defined previously in the Tables or the text.

TABLE **IV.**

Control Measurements
Ground Level *(394* m MSL)

	torr				
	SBP	DBP	PP	AP	HR(bpm)
SD + 1d $\bar{X}$	111.1	*60.4*	*50.7*	*77.3*	75.6
SD + 1d SE	4.0	*3.7*	*2.5*	*3.6*	2.7
BD + 1d $\bar{X}$	104.4*	*57.1*	*47.3*	*72.8*	73.5
BD + 1d SE	3.4	*2.3*	**1.8**	*2.6*	2.9
SD + 3d $\bar{X}$	108.8	*62.2*	*46.6*	*77.7*	72.0
SD + 3d SE	3.6	*3.1*	*2.9*	*3.0*	3.0
BD + 3d $\bar{X}$	103.7*	*59.3*	44.5	74.0	71.3
BD + 3d SE	3.5	3.1	1.7	3.1	2.2

SBP = Systolic blood pressure. PP = Pulse pressure.
DBP = Diastolic blood pressure. HR = Heart rate.
AP = Mean arterial pressure = DBP + 1/3 PP.
torr = mm of mercury pressure. bpm = Beats per min.
All other symbols have been defined previously in the Tables or the text.

TABLE V.

SBP (torr)
(During P&M test at altitude)

	6,000 ft	8,000 ft	10,000 ft
SD + 1d $\bar{X}$	109.8	113.1	110.7
SE	4.6	3.8	3.1
BD + 1d $\bar{X}$	106.9	107.3*	107.1*
SE	3.8	3.4	3.2
SD + 3d $\bar{X}$	109.6	113.2	114.4
SE	3.5	3.5	3.6
BD + 3d $\bar{X}$	110.0	110.2*	111.0*
SE	3.6	3.2	3.5

DBP (torr)
(During P&M test at altitude)

	6,000 ft	8,000 ft	10,000 ft
SD + 1d $\bar{X}$	59.6	61.7	64.5
SE	2.7	3.6	4.0
BD + 1d $\bar{X}$	58.6	57.1	59.9
SE	2.1	2.5	3.2
SD + 3d $\bar{X}$	60.7	61.7	64.2
SE	3.2	3.8	4.2
BD + 3d $\bar{X}$	59.2	60.3	59.1
SE	3.9	3.6	3.8

All symbols have been defined previously in the Tables or the text.

TABLE VI.

PP (torr)
(During P&M test at altitude)

		6,000 ft	8,000 ft	10,000 ft
SD + 1d	$\bar{X}$	49.4	51.4	46.2
	SE	3.7	3.6	2.7
BD + 1d	$\bar{X}$	47.9	50.2	47.2
	SE	2.7	2.1	2.7
SD + 3d	$\bar{X}$	48.9	51.5	50.2
	SE	3.4	3.4	3.4
BD + 3d	$\bar{X}$	51.4	51.3	52.3
	SE	2.2	2.9	2.8

AP (torr)
(During P&M test at altitude)

		6,000 ft	8,000 ft	10,000 ft
SD + 1d	$\bar{X}$	76.0	78.8	79.8
	SE	2.8	3.3	3.5
BD + 1d	$\bar{X}$	74.7	73.8*	75.6*
	SE	2.5	2.7	2.9
SD + 3d	$\bar{X}$	77.0	78.9	81.0
	SE	2.9	3.4	3.6
BD + 3d	$\bar{X}$	75.7	76.0	76.1
	SE	3.7	3.1	3.4

All symbols have been defined previously in the Tables or the text.

TABLE VII.

HR (bpm)
(During P&M test at altitude)

		6,000 ft	8,000 ft	10,000 ft
SD + 1d	$\bar{X}$	81.7	81.3	79.1
	SE	3.3	3.2	2.7
BD + 1d	$\bar{X}$	81.5	81.0	79.9
	SE	3.3	2.9	2.8
SD + 3d	$\bar{X}$	78.3	77.4	78.2
	SE	2.5	2.8	2.9
BD + 3d	$\bar{X}$	80.2	79.9	79.9
	SE	2.9	3.6	2.9

$\dot{V}_E$ (L/min BTPS)
(During P&M test at altitude)

		6,000 ft	8,000 ft	10,000 ft
SD + 1d	$\bar{X}$	8.65	8.74	8.55
	SE	0.48	0.49	0.49
BD + 1d	$\bar{X}$	8.35	8.11*	8.48
	SE	0.38	0.40	0.48
SD + 3d	$\bar{X}$	8.67	8.42	8.22
	SE	0.47	0.56	0.53
BD + 3d	$\bar{X}$	8.15	8.11	8.12
	SE	0.47	0.43	0.43

$\dot{V}_E$ = Pulmonary ventilation in L/min at body temperature and pressure, saturated.

All other symbols have been defined previously in the Tables or in the text.

TABLE VIII.

HbO_2 (Percent Saturation)
(During P&M test at altitude)

		6,000 ft	8,000 ft	10,000 ft
SD + 1d	$\bar{X}$	94.4	92.8	90.1
	SE	0.3	0.4	0.7
BD + 1d	$\bar{X}$	94.3	92.6	90.2
	SE	0.4	0.5	1.1
SD + 3d	$\bar{X}$	94.6	93.2	91.1
	SE	0.3	0.2	0.4
BD + 3d	$\bar{X}$	94.8	92.9	90.7
	SE	0.5	0.6	0.8

Ca_{O2} (mL/dL)
(During P&M test at altitude)

		6,000 ft	8,000 ft	10,000 ft
SD + 1d	$\bar{X}$	17.5	17.2	16.9
	SE	0.3	0.3	0.3
BD + 1d	$\bar{X}$	15.9*	15.6*	15.4*
	SE	0.4	0.4	0.5
SD + 3d	$\bar{X}$	17.4	17.2	16.8
	SE	0.4	0.4	0.3
BD + 3d	$\bar{X}$	15.8*	15.5*	15.2*
	SE	0.5	0.5	0.4

HbO_2 = Oxyhemoglobin saturation in percent.
Ca_{O2} = Arterial oxygen content in mL of oxygen per dL of whole blood.

All other symbols have been defined previously in the Tables or the text.

TABLE IX.

P&M Data

Arithmetic Error Score

		6,000 ft	8,000 ft	10,000 ft
SD + 1d	$\bar{X}$	111.7	104.2	103.4
	SE	18.5	14.2	18.7
BD + 1d	$\bar{X}$	159.0	193.3	192.9
	SE	52.1	53.1	74.7
SD + 3d	$\bar{X}$	107.2	91.1	50.7
	SE	24.3	9.2	14.8
BD + 3d	$\bar{X}$	125.3	126.9	102.5
	SE	36.5	24.1	33.7

Eye/Hand Coordination Error Score

		6,000 ft	8,000 ft	10,000 ft
SD + 1d	$\bar{X}$	51.9	33.9	45.9
	SE	12.9	6.1	8.7
BD + 1d	X	68.4	49.6	81.2
	SE	19.9	11.4	27.5
SD + 3d	$\bar{X}$	29.8	45.0	33.5
	SE	10.1	15.8	19.9
BD + 3d	$\bar{X}$	68.4*	60.0	45.1
	SE	22.3	23.4	16.9

All symbols have been defined previously in the Tables or the text.

TABLE X.

Orthostatic Testing

SBP (torr)

	Seated Control	Quiet Standing First min	Quiet Standing Fourth min
SD + 1d $\bar{X}$	111.6	118.8	117.6
SD + 1d SE	4.3	4.8	5.7
BD + 1d $\bar{X}$	105.0*	109.3*	111.9
BD + 1d SE	4.1	3.9	4.0
SD + 3d $\bar{X}$	109.0	116.9	118.7
SD + 3d SE	4.5	4.0	4.1
BD + 3d $\bar{X}$	106.9	114.9	115.2
BD + 3d SE	3.6	3.1	2.9

DBP (torr)

	Seated Control	Quiet Standing First min	Quiet Standing Fourth min
SD + 1d $\bar{X}$	62.5	69.1	71.4
SD + 1d SE	2.1	3.6	3.3
BD + 1d $\bar{X}$	58.5	64.7	69.7
BD + 1d SE	3.1	4.5	4.9
SD + 3d $\bar{X}$	62.1	71.1	74.6
SD + 3d SE	2.4	3.0	2.9
BD + 3d $\bar{X}$	58.6	66.9	68.4
BD + 3d SE	2.9	3.4	3.8

All symbols have been defined previously in the Tables or the text,

TABLE XI.

Orthostatic Testing

PP (torr)

		Seated Control	Quiet Standing First min	Quiet Standing Fourth min
SD + 1d	$\bar{X}$	49.2	49.8	46.2
	SE	3.0	4.9	5.4
BD + 1d	$\bar{X}$	46.5	44.6	42.2
	SE	2.1	3.4	2.2
SD + 3d	$\bar{X}$	46.8	45.8	44.1
	SE	3.6	3.0	3.0
BD + 3d	$\bar{X}$	48.3	48.1	46.8
	SE	1.8	2.9	3.0

AP (torr)

		Seated Control	Quiet Standing First min	Quiet Standing Fourth min
SD + 1d	$\bar{X}$	78.9	85.7	86.8
	SE	2.7	3.3	3.4
BD + 1d	$\bar{X}$	75.1	79.5*	83.8
	SE	3.2	3.9	4.5
SD + 3d	$\bar{X}$	77.8	86.4	89.3
	SE	2.8	3.1	3.1
BD + 3d	$\bar{X}$	74.7	82.9	84.0
	SE	3.0	3.0	3.2

All symbols have been defined previously in the Tables or the text.

TABLE XII.

Orthostatic Testing

HR (bpm)

	Seated Control	Quiet Standing	
		First min	Fourth min
SD + 1d $\bar{X}$	70.1	78.2	83.4
SD + 1d SE	2.7	3.6	3.4
BD + 1d $\bar{X}$	72.8	84.3	88.7
BD + 1d SE	3.7	4.5	4.1
SD + 3d $\bar{X}$	69.1	77.9	81.0
SD + 3d SE	2.8	3.6	3.3
BD + 3d $\bar{X}$	68.7	78.4	82.6
BD + 3d SE	2.8	4.1	3.7

All symbols have been defined previously in the Tables or the text.

TABLE XIII.

Pedal Ergometry Data

		At Max. Iso-HR	At Max. Iso-Load	
		Total Work(W x min)	$\dot{V}_E$(L/minBTPS)	HR(bpm)
SD + 1d	$\bar{X}$	577.6	34.9	126.8
	SE	67.3	2.9	2.2
BD + 1d	$\bar{X}$	443.1*	35.6	132.1*
	SE	37.3	2.6	1.2
SD + 3d	$\bar{X}$	584.4	33.5	122.6
	SE	62.8	2.2	1.8
BD + 3d	$\bar{X}$	408.7*	36.3	129.1*
	SE	40.4	2.7	1.0

Max. Iso-HR = The same maximum heart rate at which total work (W x min) values are compared

Max. Iso-Load = The same maximum total work value at which $\dot{V}$ and HR values are compared

All other symbols have been defined previously in the Tables or the text.

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