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16. Abstract

Various physiological, biochemical, and psychophysiological measurements were made on low-time private pilots who each flew three cross-country flights. The round-trip flights were 320, 520, and 960 NM in length. Heart rate was recorded continuously throughout the flights. Urine, collected for the 24-hour period surrounding the flights, was differentially analyzed for epinephrine and norepinephrine. None of the measured parameters changed in proportion to the length of the flights; however, the level of stress was high when compared to other types of flying activities. The total stress of such flights must, therefore, be considered to be in direct proportion to the length of the flights.

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PHYSIOLOGICAL RESPONSES OF LOW-TIME PRIVATE PILOTS TO CROSS-COUNTRY FLYING

I. Introduction.

A number of studies have been directed toward describing in physiological or biochemical terms the compensatory adjustments of people to work in the aviation environment. The principal thrust of these studies has been toward understanding the mechanisms of fatigue or stress that, presumably, underlie performance decrements and thus contribute to unsafe operations. Some studies have been directed toward ways of relieving the stress of flying.[1]

The study reported here is a continuation of an earlier study of the physiological responses of student pilots to flight training,[2] and is directed at identifying the elements that contribute to the sensation of weariness that is a common complaint of low-time pilots after cross-country flying.

II. Methods.

Ten private pilots, all of whom had less than 100 hours of flight experience, were given general assignments to fly, on separate days, three round-trip cross-country flights from Will Rogers Airport in Oklahoma City, in order, to Dallas Love Field (320 nautical miles), Kansas City Municipal Airport (520 NM) and El Paso International Airport (960 NM). The flights were planned to provide approximately 3, 5, and 9 hours of flight time, respectively. All flights were made in the same airplane, a new Piper Cherokee 235. One subject quit the project after the Dallas flight, another did not make the El Paso flight. All subjects were given four instructional flights in the project airplane. All flight planning was done by the subjects; they made decisions about weather, departure times, etc. They were only told where to go and to make the round trip flight in the minimum time consistent with practicality, always maintaining VFR, and to return to Will Rogers Airport before sunset.

Subjects collected urine specimens during the 24 hour period surrounding the flights according to the following schedule: Specimen Number One was collected upon arising in the morning, Specimen Number Two was collected one hour prior to flight, Specimen Number Three was collected during the period of flight and immediately post-flight, Specimen Number Four was collected from the time of completion of collection of the third specimen until bedtime. Specimens number three and four each were pooled specimens, commonly made up of several voidings; the first and second were single voidings.

The urine specimens were acidified with concentrated sulfuric acid. Twenty-five ml aliquots were frozen and stored until they were analyzed for epinephrine and norepinephrine[3] and for creatinine.[4]

Subjects were fitted with steel plate ECG electrodes positioned on the lateral chest walls and secured with an elastic strap. The ECG was amplified and recorded on one channel of an instrumentation tape recorder.

Voice transmissions were detected by a boom microphone, amplified and recorded on another channel of the tape recorder.

The continuously-recorded ECG was reduced to one-minute heart rates as previously described.[2] The voice record was used to identify the various phases and events of the flights for correlation with the heart rate.

The subjects took a psychomotor test[5] and completed questionnaires about their subjective feelings before and after each flight. Their blood pressure was taken at that time.

III. Results.

A. *Catecholamines:* The grouped results show, for all three flights, an increase of catecholamine excretion in the second and third specimens with a slight decline in the fourth specimen from the third specimen peak. The increase was greatest in the post flight (number 3) specimens and is apparent for norepinephrine as well as for epinephrine (Figs. 1–3).

The differences in the ratios of the concentrations of each catecholamine in the second, third, and fourth specimen to the concentration in the first (resting) specimen for each of the flights were computed and ranked for nonparametric statistical testing. Thus, the percentage difference in catecholamine excretion for each of the three flights was expressed. There were no points of significant difference in levels of excretion between any of the flights. Thus, the duration of the flights was unrelated to the concentration or rate of urinary excretion of the catecholamines.

B. *Heart Rate:* Average values and ranges for individuals are shown in Table I. It is noteworthy that in only five cases was the average heart rate less than 100 beats per minute. Maximum heart rates ranged from 123 to 180 bpm; minimum heart rates ranged from 56 to 111 bpm. Table II shows that 73% of the maximum heart rates occurred during terminal procedures; 27% occurred at Oklahoma City while 46% occurred at the unfamiliar airports. Sixty-one percent of the minimum heart rates occurred during the en route segments with 42% occurring outbound from Oklahoma City and 19% inbound to Oklahoma City.

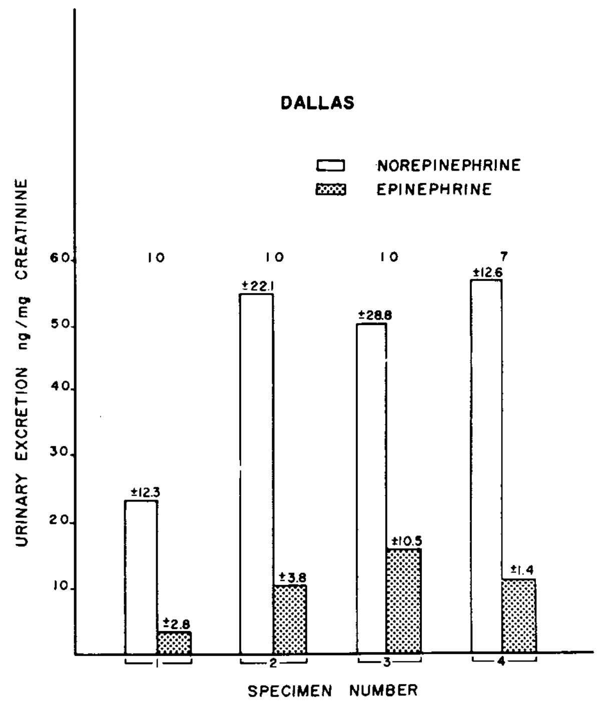

FIGURE 1. Urinary excretion of norepinephrine and epinephrine. Grouped data for the Dallas flight.

TABLE I.—Average Heart Rates with Ranges

Subject	DALLAS			KANSAS CITY			EL PASO		
	Average	Range	Percent Resting	Average	Range	Percent Resting	Average	Range	Percent Resting
1*	----	----	----	----	----	----	----	----	----
2	111	(137 90)	99.1	101	(130 82)	117.4	97	(129 70)	122.8
3	129	(157 91)	116.2	111	(134 82)	118.1	108	(154 81)	118.7
4	127	(153 101)	123.3	122	(160 95)	109.9	118	(150 94)	134.4
5**	96	(136 82)	131.5	114	(150 83)	121.3	----	----	----
6	98	(127 84)	107.7	102	(141 85)	129.1	95	(123 73)	101.1
7	113	(146 74)	120.2	111	(142 80)	118.1	109	(139 84)	116.0
8	129	(170 92)	107.5	130	(172 102)	121.5	131	(164 80)	131.0
9	108	(132 83)	104.8	88	(135 56)	117.3	109	(145 76)	112.4
10	133	(180 111)	147.8	121	(154 88)	117.5	120	(161 87)	120.0

*Recorder malfunction on Dallas flight: Subject left project without making MKC and ELP flights.
**Subject left project without making El Paso flight.

When the percentage changes in heart rate from resting were ranked and comparisons between flights were made by non-parametric statistical tests, it was obvious that there was no statistically significant difference between the

TABLE II.—Percentages of Maximum and Minimum Heart Rates Accounted for by Various Phases of Cross-Country Flights

Phase of Flight	Percentage of Maximum Heart Rates	Percentage of Minimum Heart Rates
Terminal Procedures	73%	30%
OKC	27	15
Unfamiliar Airport	46	15
Enroute	15.5	61
Outbound from OKC	4	42
Inbound to OKC	11.5	19
Other	11.5	8

flights. Thus, as with catecholamine excretion, the length of the flight was unrelated to the heart rate.

C. *Blood Pressure:* The post-flight systolic blood pressure was found to range from 98.4% to 135.8% of the pre-flight systolic pressure. Ranking of these values for testing revealed, as with the urine and heart rate values, that there was no statistically significant relationship between blood pressure and the length of the flight. Pre- and post-flight blood pressures are shown in Table III.

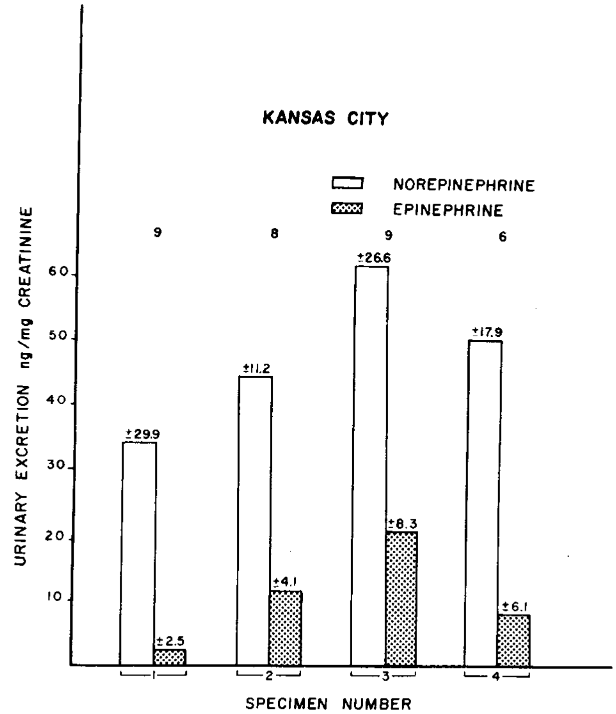

FIGURE 2. Urinary excretion of norepinephrine and epinephrine. Grouped data for the Kansas City flight.

TABLE III.—Pre- and Post-Flight Blood Pressure

Subject	DAL		MKC		ELP	
	Pre-	Post	Pre-	Post	Pre-	Post
1	118/70	128/78	---	---	---	---
2	130/74	124/82	130/72	130/80	124/78	122/76
3	148/86	142/80	148/90	144/82	132/88	152/84
4	126/80	138/88	130/80	140/80	124/78	144/84
5	126/86	132/80	132/82	130/80	---	---
6	106/62	118/68	106/58	128/78	114/60	120/70
7	140/78	146/82	146/80	144/84	132/78	160/80
8	154/90	160/94	150/92	148/80	146/88	144/88
9	118/70	140/78	114/76	130/70	106/70	144/82
10	110/75	134/66	128/78	142/84	110/78	134/72

D. *Psychomotor Tests:* It has been reported that the fatigue brought on by prolonged sleeplessness is reflected by a decrement in psychomotor performance.[6] In this study post-flight psychomotor performance was variable, sometimes declining but commonly showing improvement over the pre-flight performance. Ranking of the pre- and post-flight differences again failed to reveal any statistically valid relation to the length of flight.

E. *Correlations:* A grid was constructed upon which the significance of the relationship of each physiological and biochemical variable to all others could be charted. Only random and occasional points of significance were revealed. Thus, it is concluded that the variables measured were independent of each other.

TABLE IV.—Comparison of Various Pilot Groups' Physiological and Biochemical Responses

	Average Heart Rate BPM	NOREPINEPHRINE	μg/100 mg Creatinine	EPINEPHRINE	μg/100 mg Creatinine
X-15 (5)*	154	Parachutists (12)	9.83	Parachutists (12)	2.29
This Study	**113**	This Study	**5.49**	Student Pilots (13)	2.18
Student Pilots (2)	112	Student Pilots (1)	5.34	This Study	**1.64**
F-104 (8)	108	Simulated Flight (13)	4.84	Forest Fire Bombers (5)	1.62
Forest Fire Bombers (5)	105	Forest Fire Bombers (5)	4.03	Simulated Flight (13)	1.60
Forest Fire Bombers (9)	104	Long Flights C-135 (14)	3.81	Decompression (15)	1.18
Student Pilots (1)	103	Decompression (15)	3.74	Long Flights C-135 (14)	1.16
F-100 (10)	99	Simulated Flight (13)	3.00	Decompression (15)	0.94
Navy-Combat A-4's (11)	88	Decompression (15)	2.89	Simulated Flight (13)	0.79
		F-100 (16)	2.88	F-100 (16)	0.70
		Laboratory Personnel (16)	2.46	Laboratory Personnel (16)	0.68

*Numbers in parentheses are literature references.

IV. Discussion.

These data demonstrate that cross-country flying by low-time pilots generates physiological responses that rank quantitatively near the top of a spectrum of responses of pilots to a wide variety of flight tasks (Table IV). It is well-known that catecholamine excretion normally rises during the day. The quantities excreted by these low-time pilots, however, points to the additive effect of flight activity when compared to daytime control values from nonflying laboratory personnel (Table IV). If the term "stress" is to be employed in referring to combat and other hazardous flight activities, then that term must certainly be applicable to this group of pilots.

While the excretion of metabolic products in the urine gives a good quantitative indication of the body's response to total activity, the time resolution is rather poor. The heart rate data would lead to the conclusion that terminal procedures at the unfamiliar airports gave rise to the greatest metabolic response, for those activities account for 46% of the maximum heart rate while terminal procedures at the home airport account for only 27% of the maximum rates. The terminal activities at Love Field, Kansas City Municipal Airport, and El Paso International Airport must be considered as short-term stressors of considerable intensity. It would be expected that the metabolites produced in response to those stressors would be diluted by the urine produced during the comparatively peace-

TABLE V.—Mean Total Excretion of Catecholamines (μg) in the Number Three Specimen

Subject Number	DALLAS E	DALLAS NE	DALLAS Total	KANSAS CITY E	KANSAS CITY NE	KANSAS CITY Total	EL PASO E	EL PASO NE	EL PASO Total
1	5.1	11.6	16.7	----	----	----	----	----	----
2	3.7	24.3	28.0	11.8	41.4	53.2	3.9	33.6	37.5
3	4.6	18.1	22.7	4.7	14.7	19.4	11.3	34.8	46.1
4	0.8	3.7	4.5	12.1	63.0	75.1	3.4	23.0	26.4
5	8.9	5.3	14.2	13.1	21.3	34.4	----	----	----
6	5.8	17.0	22.8	3.9	24.4	28.3	6.5	34.0	40.5
7	1.1	19.1	20.2	6.2	14.5	20.7	10.2	32.1	42.3
8	8.9	17.8	26.7	11.8	31.9	43.7	18.5	49.9	68.4
9	6.8	7.9	14.7	6.2	7.4	13.6	4.7	24.3	29.0
10	5.7	19.0	24.7	5.6	27.0	32.6	6.0	29.0	35.0
AV	5.1	14.4	19.5	8.4	27.3	35.7	8.1	32.6	40.7
SEM	0.9	2.2	2.3	1.2	5.6	6.4	1.8	3.0	4.6

ful en route phase of the return to Oklahoma City. If that is the case, then the dilution was not great enough to cause significant differences in the concentration (or rate of excretion) of urinary catecholamines for the three flights.

Since the concentrations or excretion rates are not significantly different, it must be concluded that the total excretions are different in proportion to the length of the flights (Table V).

It is concluded, therefore, (1) that the level of stress is essentially equal for the three flights and is comparatively high. However, by considering only the level of stress, reflected in the concentration of catecholamines in the urine, consideration of the time-dependent factor of stress is neglected, leading to the conclusion that (2) the total stress of these flights is an integral of the level of stress and the time over which it is applied. It is further concluded (3) that terminal procedures at the three unfamiliar airports acted as rather powerful stressors of short duration compared to the duration of the entire flight.

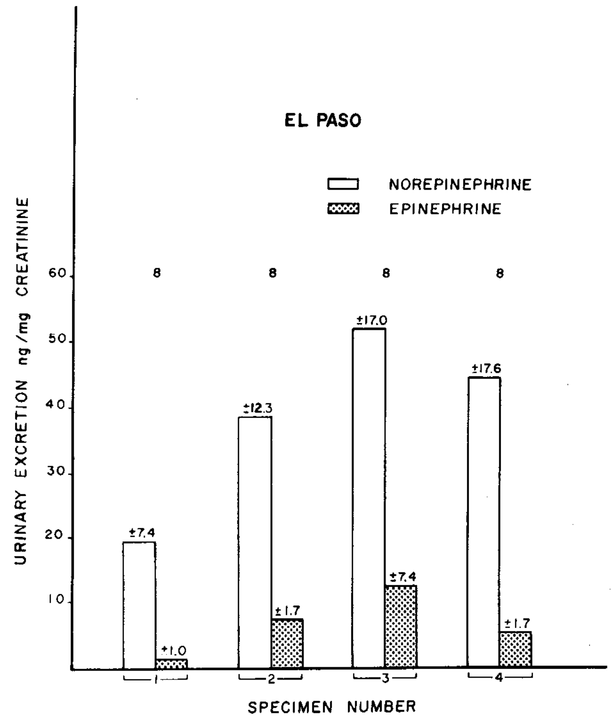

FIGURE 3. Urinary excretion of norepinephrine and epinephrine. Grouped data for the El Paso flight.

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