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ENDOCRINE-METABOLIC RESPONSES TO PARACHUTING

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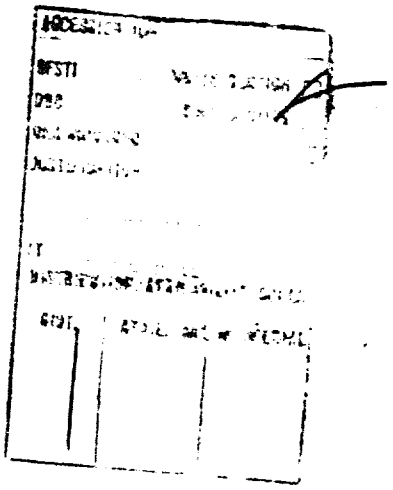

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FOREWORD

This is a report of a collaborative research study which involved personnel at Wurtsmith AFB, Mich., and personnel in the Physiology Branch, USAF School of Aerospace Medicine, the latter group working under task No. 775801. The field and laboratory phases of this study were accomplished in the period between February and July 1966. The paper was submitted for publication on 24 April 1968.

The authors acknowledge the technical help of H. W. Avery, J. K. Farquhar, J. B. Garcia, Jr., and R. E. Miranda.

This report has been reviewed and is approved.

GEORGE E. SCHAFER
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ABSTRACT

This was a feasibility study in which the usefulness of urinalysis for the assessment of stress in parachutists was tested. Eight sport parachutists were studied, each collecting urine specimens on two separate occasions, with each specimen representing a 2-hour period which included ascent to altitude, the jump, and a postjump rest period. The urinary determinations included epinephrine, norepinephrine, 17-hydroxycorticosteroids, magnesium, potassium, sodium, phosphorus, urea, and creatinine. Creatinine served as the base to which the other eight constituents were referred. The individual urinary constituents, when expressed as percent of respective control values and averaged, gave a single value for the endocrine-metabolic response, the so-called stress index or score. Five of the jumpers were novices whose jumps were made at lower altitudes than were used by the remaining 3 jumpers who were highly experienced. Sympathoadrenomedullary stimulation of high degree was evident for all but one of the jumpers, but few of the jumpers showed evidence of adrenocortical stimulation or of metabolic hyperactivity. The stress score was 162% for the novice group, 225% for the experienced group, and 186% for the entire group. The latter value differed significantly from zero ($P < .001$).

ENDOCRINE-METABOLIC RESPONSES TO PARACHUTING

I. INTRODUCTION

From the medical standpoint, more knowledge is needed as to the character and magnitude of stress responses of flying personnel. Urinalysis has been shown to be a practical means for quantifying stress responses in aerospace operations of relatively long duration (5, 7, 9, 10), but its usefulness for appraising short-duration stress, such as that incurred during parachuting, seems to be unsettled. Hatch et al. (8), who used a battery of urinary determinations, including 17-hydroxycorticosteroids, in a study of parachutists, concluded that the endocrine-metabolic change associated with jumping from training towers or from aircraft was neither widespread nor of significant magnitude. Bloom et al. (2) reported that urinary epinephrine, but not norepinephrine, was consistently increased when parachutists (either trainees or instructors) jumped from towers or from aircraft. Both of the above-mentioned groups of investigators used urine specimens that represented periods of 3 to 4 hours, and it may be that these are not the most suitable time intervals for accurate analysis. The present effort was a feasibility study which was run to settle questions about the usefulness of short-duration urine collections in parachute stress studies, thus obtaining guidance for definitive studies.

II. METHODS

Eight members of a sport parachutist group were studied. Three were experienced jumpers, having made 150 to 250 free-fall jumps. The remaining 5 were novices who were either on their "static line" or "clear and pull" jumps. Most of the subjects were members of an aircraft maintenance squadron; so control data were obtained from 22 other aircraft maintenance men who were doing accustomed indoor work, with the time of their urine collections either the same or almost the same as that for the parachutists. Each jumper was studied after two jumps made on separate days, using urinary specimens that represented 2-hour periods which began just before the time of donning the parachute preparatory to ascent to altitude. Each specimen represented three events: (a) the ascent to altitude; (b) the jump; and (c) a postjump rest period (with the jumpers indoors, because the tests were made in winter). Ascent time was a variable factor, amounting to approximately 20 minutes for the novices (who went to altitudes between 2,800 and 3,500 feet) and to approximately 40 minutes for the experienced jumpers (who went to altitudes between 7,200 and 12,500 feet). To facilitate jumping, the door of the aircraft had been removed before ascent; consequently, the subjects were exposed during ascent to a 90-m.p.h. windblast, with air temperature ranging from 0° to 15° F. (−18° to −9° C.).

The urine specimens were collected into dilute hydrochloric acid (with further dilution to give standard pH), promptly frozen, and shipped in the frozen state to the laboratory, where they were analyzed by automated means for creatinine, urea, phosphorus, potassium, and sodium. Additional analyses included magnesium (12), 17-hydroxycorticosteroids (11), norepinephrine (3), and epinephrine (3).

III. RESULTS

Table I presents the urinary data for the individual parachutists, with the inexperienced and experienced jumpers identified. Each value for the individual jumpers is the average

TABLE I

Excretion trends for parachutists

Jumper	Urinary variable*										Stress index (%)
	E (μg.)	NE (μg.)	(NE/E) (μg./μg.)	17-OHCS (μg.)	Urea (mg.)	P (mg.)	Mg (mEq.)	K (mEq.)	Na (mEq.)	(Na/K) (mEq./mEq.)	
Inexperienced											
A	2.28	8.56	(3.9)	292	884	41	.52	2.0	5.2	(2.6)	158
B	1.52	6.47	(4.3)	708	897	26	.62	3.3	10.3	(3.3)	154
C	1.97	4.87	(2.6)	350	1,004	46	.63	3.1	6.7	(2.2)	142
D	3.23	8.06	(3.2)	333	1,188	48	.54	7.2	5.6	(0.8)	195
E	1.58	9.98	(6.6)	388	795	28	.64	2.4	7.6	(3.0)	160
											$\overline{X} = 162$
Experienced											
F	1.96	9.22	(4.2)	466	1,314	34	.70	3.6	11.8	(3.6)	182
G	0.52	2.94	(5.8)	262	746	44	.56	2.2	4.5	(2.1)	86
H	5.26	28.52	(5.7)	582	1,750	56	1.12	4.6	18.0	(5.4)	408
											$\overline{X} = 225$
All jumpers (n = 8)	2.29	9.83	(4.5)	423	1,072	40	.67	3.6	8.7	(2.9)	186
Control (n = 22)	0.59	2.03	(3.7)	336	1,198	57	.37	4.9	11.8	(2.5)	100

*Quantity per 100 mg. creatinine, unless otherwise indicated. The stress index for each subject is the average of the eight urinary constituents, each of which was expressed as percent control (Na/K and NE/E were excluded in making this computation and therefore are given in parentheses).

of two determinations, one for each jump. In addition, the mean value for the 8-man group is presented for each urinary variable. The control values are the means for the 22-man unstressed group. The various urinary constituents have been expressed as creatinine-based ratios (quantity per 100 mg. creatinine), following a practice frequently used in field studies of various sorts, including flying operations. Additionally, an overall value (the so-called stress index or score) has been derived for each jumper. This index incorporates the data for the eight urinary constituents (P, Mg, K, Na, urea, 17-OHCS, epinephrine, and norepinephrine). To place these different variables on a common scale, each was expressed as percent of its control value, after which the average of the eight values was computed. Because the special ratios, Na/K and NE/E, were not used in making this computation, they are enclosed in parentheses in the table.

High interindividual variability is evident, and it seems to have been greater in the experienced subgroup than in the inexperienced subgroup. For example, the epinephrine values for the experienced jumpers ranged from 88% to 892% of the control, while those for the inexperienced jumpers ranged from 258% to 547% of the control. The variability in norepinephrine for the experienced jumpers also exceeded that for the inexperienced jumpers. The stress scores also show high variability, and the experienced jumpers have the higher spread in scores.

The relatively high catecholamine values imply sympathoadrenomedullary hyperactivity, a nonspecific stress response. For the group as a whole, the epinephrine and norepinephrine values amount to 388% and 484% of the respective controls. Compared to sympathoadrenomedullary responses that we have observed under other circumstances (flying or laboratory stress studies), these are relatively high in magnitude. Of interest is the finding that the experienced subgroup contained both the least responsive and the most responsive of all the jumpers, as judged by urinary epinephrine and norepinephrine values. Despite the differences in their catecholamine values, these two jumpers had almost identical NE/E ratios—both values approaching 6.1, a value which exceeds the control value. These values are relatively high, as the NE/E ratio for the entire group of jumpers approximates 4.1, as does the NE/E ratio for the control group. The NE/E value for the entire group is the mean of the eight individual NE/E ratios, not the ratio of the mean norepinephrine and mean epinephrine values (which gives a slightly lower value).

Adrenocortical hyperactivity, which is also a nonspecific stress response, was not consistently indicated. Only 3 of the 8 jumpers had 17-OHCS values that greatly exceeded the control value. Two of these were in the experienced subgroup, and their 17-OHCS values amount to only 125% and 173% of the control value. The remaining man, an inexperienced jumper, had a value amounting to 211% of the control, which represents an adrenocortical response of fairly high magnitude.

Metabolic hyperactivity, which is another nonspecific stress response, was not generally evident. However, all of the jumpers had relatively high magnesium values, the mean magnesium value for the entire group amounting to 180% of the control.

The individual stress scores reflect primarily the increases in urinary catecholamines, but the other urinary variables had modifying influence, tending to diminish the magnitude of the aggregate endocrine-metabolic response. The stress score for the entire group amounts to 186% of the control, and this value differs significantly from zero ($P < .001$).

IV. DISCUSSION

While the first known parachute was designed by Leonardo da Vinci in the 14th century, it was not until modern times that parachuting came into its own. The successful use of paratroops by both the Axis and the Allied armies in World War II and the later development of free-fall technics in France led to a growing interest in skydiving. Because of current medical interest, various approaches have been used to quantify physiologic reactions

to parachuting. Bloom et al. (2), who made heart rate, blood eosinophil, and urinary catecholamine determinations, reported increases in heart rate and urinary epinephrine without consistent increases in urinary norepinephrine. The present results differ in that there were consistent increases in both epinephrine and norepinephrine. The above-mentioned investigators concluded that parachute stress reactions are not subject to habituation, basing this conclusion upon the finding that instructors and trainees did not differ significantly in their heart rate and urinary epinephrine responses to parachuting. Nevertheless, Fenz and Epstein (4), who monitored heart rate, galvanic skin resistance, and respiratory frequency immediately before and during ascent in aircraft and again after completion of a jump, found that inexperienced and experienced jumpers were clearly differentiated on these various bases. For example, heart rates for inexperienced jumpers increased progressively both during the period of flight preparation as well as during ascent, while heart rates for experienced jumpers increased progressively in the preflight period and tended to plateau during ascent. Schane and Slinde (13) went further, monitoring heart rate during free fall in 29 jumpers who made 98 jumps. They found that the tachycardia induced by free fall, contrary to expectation, increased as the jumpers gained in experience, and this was interpreted as evidence of nonadaptation. There is, therefore, basic agreement with the previously mentioned findings of Bloom et al. (2). The present findings for experienced and inexperienced jumpers seem to be in accord with those of Schane and Slinde (13) in that the experienced jumpers, as a group, showed the higher sensitivity to parachuting as judged by the mean stress index. The fact that one experienced jumper appeared to be unresponsive suggests that adaptation can occur.

Since the jumpers in the present study were exposed to cold air during the ascent to altitude, as well as during the jump, some of the stress that was detected may have been cold-induced. This seems likely since Arnett and Watts (1) demonstrated increases in urinary epinephrine and norepinephrine excretion in men exposed for only 1 hour to mild cold (6.5° C.), the epinephrine and norepinephrine gains amounting to 180% and 128% of the respective control values

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