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Changes in Some Haematological Parameters During Severe Heat Stress in Man

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13 healthy adult volunters were exposed for 50 mts in a hot environment of 57°C DB and 37.5°C WB (Oxford Index 38.7°C) with a wind velocity, 55 ft/min. Highly significant rise in the value of Haemoglobin % ($P \angle 0.001$), PCV ($P \angle 0.001$) and fall in ESR ($P \angle 0.001$) were observed. Total blood water loss was 2.13% ($P \angle 0.05$). This indiciates a definite occurrence of haemo-concentration. Eosinophil count showed a highly significant ($P \angle 0.001$) reduction of 33.2% after the exposure. This is an indication of severe stress during the heat exposure. A significant fall in the concentration of blood bicarbonate ($P \angle 0.001$) and Hydrogenions ($P \angle 0.5$) were also observed. This provides some insight into the bio-chemical changes during heat stress. As the controversy regarding the blood volume during heat stress is resolved to some extent by this study, the importance of fluid intake before a sortie in summer months is highlighted. The eosinophil count can be utilised at field level as a very simple test to evaluate the presence of stress.

During summer, especially in the northern regions of India aircraft cockpit temperature recorded during low level flights have been as high as 50-60°C. The pilot in the cockpit of such an aircraft is thus subjected to very severe heat stress. (Dikshit 1980, Sinha etal 1969, Verghese etal 1969, Iyer etal 1984)[2,11,5]. The existence of high heat loads are also well known to metal, glass, ceramics, mining and in many other industries (Gupta 1982)[3]. Therefore heat stress has become an unavoidable stress of this era which is present wherever men inhabit and flourish. This has special significance in the field of military aviation because of its adverse effect on the physiology and hence to the performance of the aircrew. Various aspects of acute heat stress has been studied by different workers (Blockly etal 1954, Sinha etal 1969, Dikshit etal 1980, Iyer etal 1984) [1,11,5]. But its effects on haematological parameters in man has not been studied by many (Ohira etal 1981).[7] Considering the vital physiological role played by blood, it was considered worthwhile to study the effects of heat on haematological parameters.

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Materials and Methods

Thirteen healthy adult male unacclimatized volunteers with mean age 33.28±7.48 yrs, height 171.64±5.46 cms, weight 63.08±6.37 kg took part in this study. The hot environment in which this study was conducted was one 57°C, DB, 35.5°C WB, 25% RH (Oxford Index 38.7°C) for a period of 50 minutes as encountered commonly in a low level fighter mission during summer. Subjects wore routine flying clothing during the experiments. The experiment was initiated at 10 AM after an overnight fasting. 8 ml of blood was withdrawn from brachial vein of the seated subject after 30 minutes rest in the laboratory. Although a cuff (or mannual pressure) was used to engorge the vein, the blood was taken approximately 10-15 seconds after the occlusive effect is removed. From the syringe about 5 ml of blood were equally divided and immediately transferred to two small bottles containing 3.8% sodium accetate and 2:3 double oxalate respectively for the measurement of Haemoglobin, Haematocrit, ESR, TLC, and leucocyte differentials. The estimation were done by conventional methods. The remaining blood was allowed to clot. The serum was separated by centrifugation for determination of Na^+, K^+ (Flame photometry) Cl^- (Schales & Schales)[8]. Blood was also collected in capillary tubes from a finger prick for HBO_3^-, H^+, PCO_2 (AVL auto analyser). A post heat exposure blood sample was taken and all the tests were repeated after the heat exposure. The blood water content (W) is calculated by the formula.

$$W\ (g/100\ ml) = -0.89 \times Hb\ (g/100\ ml) + 91.4 \quad \ldots\ldots\ldots\ldots (1)$$

Actual amount of water lost (D) is calculated as

$$D\ (g/100\ ml) = \frac{((100 - W\ post) \times W\ pre - (Solid\ per) \times W\ post)}{100 - W\ post} \quad (2)$$

Where W pre and W post were calculated from W using equation (1) Solid pre (g/100 ml) = 100-W pre ....(3)

Further use of Hb as the index allows the calculation of blood parameters corrected for effects of haemo concentration by formula :

$$Se = S\ pre - S\ Post - Hb\ post \times \frac{S\ pre}{Hb\ pre} \quad \ldots\ldots\ldots\ldots (4)$$

Where Sc is the corrected level of each pa meter and S pre, S post and Hb pre, Hb post the determined values of parameters and haemog bin respectively before and after the exposure heat.

All the above formulae were taken from Oh etal (1981, 1977)[6,7].

The total loss of water during the exposure w calculated from the difference in the body weig before and after the exposure.

Results

Body weight decreased by 1.17% ($P \angle 0.05$) d to water loss. The percent decrease of water lo calculated by using haemoglobin level (W pr W post) is 0.46% of pre valve. However by usi formula for incremental water loss (D), the absolu water loss was 2.13% (Table I). Haemoglob increased by 2.96% ($P \angle 0.001$) ESR fell by 41.8 ($P \angle 0.001$) HCT showed a significant ($P \angle 0.00$ rise by 5.63% (Table IIA). Total leucocytes increa ed by 1.93% (NS). Differentially polymorpl increased by 3.6% (NS) Basophils increased 70.83% (NS) Lymphocytes increased by 0.83% (N Monocytes increased by 33.1% (NS). The Eosino hils decreased significantly by 33.2% ($P \angle 0.00$ (Table IIIB). Bicarbonate increased by 5.79 ($P \angle 0.01$) and hydrogenion concentration reduce by 11.77% ($P \angle 0.05$) (Table IIIA). There was a insignificant fall of sodium by 0.14% and a nea significant ($t = 2.02$) increase of potassium by 6.8 (Table IIB). Serum chloride increased by 2.86 ($P \angle 0.05$) (Table IIB).

Discussion

Ohira etal (1981) reported 1.3% loss of bloo water when human subjects were exposed to saun bath for 40 minutes. In this study the subject though exposed to a different heat exposure profile showed a 2.3% fall in total blood water. This los can be accounted for the loss of water as sweat. A short duration exposure to moderately severe hea stress in resting subjects produces a weight loss o about 1% as reported by Harrison (1978) an

Dikshit etal (1980). But as to whether this loss of body fluids results in lessening of plasma volume per se or not is debatable. Seney and Christenson (1965, 1968) reported an initial plasma dilution with a fall in haematocrit by 3.5%. Harrison (1974) on the other hand reported a rise in haematocrit by about 4% at the end of 50 minutes of exposure to a severe heat stress. The findings in this study settles the controversy about the volume of blood during heat stress. On the basis of this it can be suggested that the hydration status has a very important role to play in reducing the ill effects of heat stress. As far as the electrolytes are concerned, there is no marked change in their levels. It is interesting to note that whatever changes found in the serum electrolytes and that in the number of the circulating leucocytes, they are very similar to the changes which are seen during severe physical exercise (Ohira et al 1981). It can therefore be assumed that heat stress can produce a similar fatiguing effect on seated subjects as if he was doing some sort of severe physical exercise. Thus an additional stress of any kind - physical work-in such situation can affect the physical and mental capability of the pilot very adversely.

As the controversy regarding the blood volume during heat stress is resolved to some extent by this study, the importance of fluid intake before a sortie in summer months is highlighted.

The significant reduction of the eosinophil may be an index of stress. The eosinopenic effect of stress is known (Tatai 1957, Wintrobe 1974). This lowering may due to increased margination of these cells or even may be due to their destruction. Whatever be the cause of this reduction, the effect is highly consistent. So it can be utilised at field level as a very simple test to evaluate the presence of stress.

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TABLE I

ESTIMATED LOSS OF BLOOD WATER BEFORE AND AFTER HEAT STRESS

(In gms/100 ml of blood) (n=13)

Subject Number	Hb gm %		Blood Water Content (W)*		Actual water loss (D)*
	Pre	Post	Pre	Post	
1	15.00	15.40	78.1	77.7	1 60
2	15.10	15.40	77.0	77.7	1 20
3	14.60	15.10	78.4	78.0	2.02
4	14.80	14.90	78.2	78.1	0.41
5	14.60	14.80	78.4	78.2	0.82
6	14.80	15.30	78.4	77.8	2.80
7	14.60	15.00	78.4	78.0	1.62
8	12.00	12.60	80.7	80.2	2.70
9	14.50	14.90	78.5	78.1	1.63
10	14.50	15.00	78.5	78.1	2.03
11	14.50	15.00	78.5	78.1	2.03
12	15.00	15.50	78.1	77.6	1.98
13	14.60	14.80	78.4	78.2	0.82
Mean	14.51	14.94	78.50	78.14	1.70
SD	0.78	0.73	0.69	0.65	0.71
Mean difference		0.43		−0.36	
't' value		9.44		14.78	
'p' value		∠0.001		∠0.05	
SE					0.20

* W & D were calculated by the formula of Ohira et al (1977, 1981) [6,7]

TABLE II A

HAEMATOLOGICAL PARAMETERS BEFORE AND OR AFTER HEAT STRESS (n=13)

Subject Number	Hb gm %		ESR mm/Hr		PCV %	
	Pre	Post	Pre	Post	Pre	Post
1	15.00	15.40	9.00	4.00	46.00	50.00
2	15.10	15.40	3.00	1.00	45 00	49.00
3	14.60	15.10	7.00	4.00	44.00	47.00
4	14.80	14.90	3 00	2.00	46.00	48.00
5	14.60	14.80	4.00	3.00	49.00	51.00
6	14.80	15.30	4.00	2.00	48.00	51.00
7	14.60	15 00	5.00	4.00	50.00	51.00
8	12.00	12.60	5.00	4.00	40.00	43.00
9	14.50	14.90	7.00	3.00	47.00	49.00
10	14.50	15.00	9.00	4.00	47.00	50.00
11	14.50	15.00	3.00	1.00	46.00	48.00
12	15.00	15.50	8.00	7.00	44.00	46.00
13	14.60	14.80	4.00	2.00	48.00	52.00
Mean	14.51	14.94	5.46	3.15	46.15	48.85
SD	0.73	0 73	2.26	1.62	2.58	2.48
Mean difference		0.43		−2.31		2.7
't' value		9.44		5.67		19.25
'p' value		∠0.001		∠0.001		∠0.001

TABLE II B

CHANGES OF SERUM ELECTROLYTES DURING HEAT STRESS (n = 13)

Subject Number	Electrolytes				mmo1/1	
	Sodium		Potassium		Chloride	
	Pre	Post	Pre	Post	Pre	Pos
1	136.4	138.0	4.00	4.80	102.0	107.0
2	143.3	136.7	5.10	4.20	104.0	101.0
3	140.2	141.0	4.10	4.60	101.0	104 0
4	132.1	136.7	3.40	4.00	103 0	104 0
5	136.0	138.9	4.60	4 80	104.0	105.0
6	138 0	141.2	4.20	4 80	99.0	103.0
7	143.5	147.0	3.30	3.80	103 0	103.0
8	140.0	142.0	4 10	4.50	105.0	107.0
9	138.0	132.0	4.00	4.50	100.0	110.0
10	147.0	132.0	5.40	5.40	104.7	101.2
11	147.4	151.2	5.01	5.80	108.2	110.6
12	153.9	149.8	5.01	.560	117.7	123 5
13	147.9	154.4	5 00	5.60	111.0	123.0
Mean	141.8	141.6	4.40	4.70	104.9	107.9
SD	6.0	7.1	0.67	0.60	4.97	7 43
Mean difference		-0 2		0.30		3.0
't' value		0.15		0.02		2.43
'p' value		NS		Near significant		∠0.05

TABLE III A

CHANGE OF SERUM BICARBONATE, BLOOD pH AND HYDROGENION CONCENTRATION DURING HEAT STRESS (n=13)

Subject Number	$-HCO_3$ mmol/1		PH		H ion conc mmol/l	
	Pre	Post	Pre	Post	Pre	Post
1	27.2	25.9	7.480	7.580	3.31	26.3
2	25.4	24.8	7.418	7.451	38.0	35.4
3	21.5	22.1	7.400	7.410	39.8	33.9
4	27.2	24.2	7.480	7.453	33.1	35.2
5	26.3	25.3	7.435	7.465	39.7	34.3
6	25.3	24.5	7.412	7.435	38.7	36.7
7	24.4	24.7	7.445	7.471	35.9	38.8
8	23.3	19.3	7.427	7.539	37.4	28.9
9	26.8	26.6	7.478	7.870	33.3	13.5
10	26.7	25.6	7.471	7.505	33.3	31.3
11	32.7	30.1	7.525	7.558	29.9	27.7
12	24.6	23.0	7.553	7.463	35.2	34.4
13	25.8	21.3	7.433	7.471	36.9	36.8
Mean	25.9	24.4	7.451	7.513	35.53	31.56
SD	2.61	2.66	0 035	0.124	2.80	6.53
Mean difference		-150		00.62		-3.97
't' value		3.48		2.14		2.64
'p' value		∠0.01		Near Significant		∠0.05

TABLE III B

WHITE CELL COUNTS BEFORE AND AFTER HEAT STRESS (n=13)

Sub.	*TLC/cmm		DIFFERENTIAL COUNT / cmm									
			Poly		Eosi		Baso		Lympho		Mono	
No.	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Pos
1	8800	8965	5104	5016	264	177	0	0	3256	3593	176	179
2	6200	6878	3596	4129	186	136	62	139	2232	2266	124	208
3	5000	5428	2800	3152	200	105	50	54	1800	1898	150	219
4	7200	6752	4608	4185	432	201	72	136	1872	2095	216	135
5	4400	4841	2288	2419	176	145	0	0	1848	2131	88	146
6	7900	8534	4898	5643	395	163	0	88	2528	2467	79	173
7	6000	4836	3840	3045	300	142	60	48	1620	1456	180	145
8	6100	6095	3538	3535	305	305	0	64	2196	2130	61	61
9	7000	7307	3710	4248	700	431	0	0	2240	2338	350	290
10	6600	6773	2432	3242	132	135	0	0	2970	3188	66	208
11	8900	8703	5762	5021	258	171	0	0	2408	3247	172	264
12	8600	8614	4472	5131	344	429	0	0	3612	2784	172	170
13	7200	7702	4032	5171	216	75	72	0	2592	1832	288	620
Mean	6892	7025	4006	4149	301	201	24	41	2398	2418	163	217
Sd	1368	1436	953	1007	149	115	32	53	594	621	87	134
Mean diff.		133		143		—100		17		20		54
't'		0.95		0.88		3.44		1.33		1.62		1.81
'p'		NS		NS		∠0.01		NS		NS		NS

*Post exposure cell counts are corrected by the formula of Dhira et al (1981)[7].