Original Article

Haematological Changes in Man during 12 hour exposure to Simulated Hypogravity by Dry Immersion Technique

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Nineteen healthy male adult volunteers were the subjects to study the changes in haemoglobin concentration (Hb), hematocrit (Hct) and percentage change in plasma volume (PV) during 12 hour exposure to simulated hypogravity by Dry Immersion method (DI).

Hb and Hct decreased significantly by 1 hour but showed an increasing trend thereafter. Percentage change in PV, as calculated from Hb and Hct, indicated significant increase at 1 hour. Thereafter it showed a trend toward decrease which became statistically significant by 8 and 12 hours of DI. Hb, Hct and PV returned to pre-immersion level in recovery sample, taken 12 hours after completion of experiment. Redistribution of body fluids during simulated weightlessness probably explains the above changes.

Key words : Plasma volume changes, simulated weightlessness, water immersion.

The significant hematological changes of spaceflight are reduction in plasma volume & alteration of red cell mass[1]. It is felt that studies on hematological changes during ground simulation of weightlessness would provide useful data in this regard.

Shulzenko and Vil-Vilyams[2] described a modification of water immersion model by keeping the subject away from direct contact with water by interposing a thin water proof sheet. This model of Dry Immersion (DI) is a better analog of weightlessness as it neither has the problem of skin maceration and maintenance of hygiene inherent in water immersion nor it has the discomforts of Head Down Tilt (HDT)[1,3]. Very little data has however been generated through this method on accounts of its recent orgin. DI facility has been installed at this Institute only very recently[4].

The present study reports haemoglobin concentration (Hb) hematocrit (Hct) and plasma volume changes, indirectly calculated from Hb and Hct, during 12 hours of DI as compared to the control values.

Material and Methods

Nineteen healthy male adult volunteers (age 22.3 1.84 yr) were the subjects of this study. All were nonsmokers. The subjects were briefed to avoid alcohol, to have normal diet and proper sleep during the period of the study. They were familiarised with the equipment. Informed consent was obtained after the details of the study procedure were explained to them. Each subject served as his own control a day prior to DI study.

On the day of experiment, the subject reported to laboratory at 0700 hrs after breakfast. He was asked to pass urine which was discarded. He changed into a cotton vest and well fitting pyjamas. He was asked to lie supine on the raised platform of DI tank for thirty minutes before being subjected to DI by lowering the platform into the tank. The detail design of the DI system has been reported earlier[4].

During both control and experimental study, the subjects are not allowed food and drink during the 1st 5 hour. Then they were served lunch which consisted of 150g of rice, 100g of cooked Dal and 300ml of water.

The antecubital venous blood samples were drawn at 1hr, 4hr, 8hr, and 12hr of DI, and were collected in pitcher bottle using double oxalate as an anticoagulant for haematological studies. Control samples were drawn a day prior at the same timings. A blood sample was also drawn 12 hours after the completion of DI to assess the recovery state. Hb was measured by

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cyanomethemoglobin method. Hct was determined by Wintrobe's method. Hct values were corrected for trapped plasma by multiplying with a factor 0.96[5]. Percentage change in PV was calculated by formula given by Harrison[6]:

$$\% \text{ Change in PV} = \left[\frac{(Hb1) \times (1-Hct\ 2)}{(Hb2) \times (1-Hct1)} - 1\right] \times 100$$

Hb1, Hct1 - for control values
Hb2, Hct2 - for DI values

The total quantity of urine passed during 12 hr exposure to DI was collected and measured. About 100ml of pooled sample was taken in a plastic bottle containing 1ml of 6N HCl and kept refrigerated for estimation of urinary sodium concentration. Control sample of urine was collected a day prior to DI for comparison.

Results

The mean Hb showed significantly lower values at 1 hour of DI as compared to control value ($p<0.01$). Thereafter, it showed an increasing trend but the differences from the control were not significant. The mean values of Hct also showed significantly lower values at 1 hour of DI as compared to control value ($p<0.01$). Thereafter it started increasing and the difference with the control became significant ($p<0.01$) at 12 hour of DI. The percentage change in PV showed a significantly ($p<0.01$) higher value over control by 11.7% at 1 hour of DI. Thereafter, it showed a decreasing trend and the values became significantly less than the control at 8 hour (6.9%, $p<.01$) and 12 hour (11.2%, $p<.01$). 12 hour after DI, Hb%, Hct, % change in PV returned close to 1 hr control values (Table I).

Urine output for 12 hours period during DI (1085 ml) was significantly higher ($p<0.01$) than control value (764 ml) and the specific gravity of pooled sample of urine during DI (1015) was significantly lower ($p<0.01$) as compared to control value (1021). Urine sodium concentration was significantly higher during 12 hour exposure to DI as compared to control value (table II).

Discussion

In the present study hemoglobin concentration and Hct value at 1 hour of DI indicated an early haemodilution. McCally[7] observed a decrease of Hct half an hour after immersion. He estimated that mean PV increased by 9% which was followed by a progressive increase in Hct during subsequent 6 hour of immersion, suggesting a decrease in PV.

Table I : Hb concentration, Hematocrit and plasma volume changes during DI as compared to control values (m ± sd, n=19)

Duration (hr)	Hb (g/dl)			Hct (%)			Change in PV (%)
	Control	DI	Mean Diff.	Control	DI	Mean Diff.	
1	15.0 ± 1.4	14.4 ± 1.4	-0.6**	44.1 ± 3.2	40.3 ± 2.9	-3.8**	11.7 ± 6.1
4	14.8 ± 1.4	14.6 ± 1.6	-0.2	42.4 ± 3.6	42.3 ± 4.5	-0.1	1.5 ± 12.1
8	14.7 ± 1.3	15.1 ± 1.2	0.4	41.4 ± 3.5	43.7 ± 3.7	2.3	-6.9** ± 8.1
12	14.5 ± 1.4	15.2 ± 1.3	0.7	40.9 ± 3.7	44.8 ± 3.7	3.9**	-11.2** ± 7.9
Recovery (12 hr after completion of DI run)		15.1	0.1		45.0	0.9	0.0 ± 1.3

**P<0.01

Table II : Urine parameters during DI as compared to control values (m ± sd)

Urine Parameters	Control	DI	Mean Diff.
Volume, ml (n=19)	761 ± 231	1086 ± 380	325**
Specific Gravity (n=19)	1021 ± 2	1015 ± 2	-6**
Na^+ Conc mmol/l (n=7)	92.3 ± 39.4	103.7 ± 26.6	11.5**

** p<0.01

There is an immediate increase in central volume due to cephalad shift of fluid followed by further increase in PV during 1 hour of immersion.[5,8-10] It has been suggested that increased hydrostatic pressure imparted to interstitial tissue by immersion perturbs the balance of Starling forces controlling fluid filtration and reabsorption between capillary and interstitium. As a result of alteration in transmural pressure in the capillaries especially of the lower extremities in the immersed state, there is a net reabsorption of interstitial fluid into the circulation[11]. This is indicated by reduced interstitial fluid pressure during the first hour of immersion. An alternative hypothesis has been suggested. The initial decrement in Hct may be secondary to an immersion induced compression of small venules in the preriphery with the transfer of hypotonic fluid with a lower Hct into the vascular system[9,11].

Subsequent reduction in PV could be due to diuresis, natriuresis or reduced fluid intake during immersion[7,9,11-13]. In the present study urine output and urinary excretion of sodium was significantly (p<0.01) higher as compared to control values.

Greenleaf et al[9] found a reduction in PV by 12.6% following 8 hour of immersion. He also noted that total reduction in extracellular fluid was proportionately divided between interstitial fluid volume and PV.

Diuresis was first noticed by Bazette et al[14] and has been the striking feature of all immersion studies[7,11,14-17]. The neural, hormonal and haemodynamic factors have been implicated in mediating diuresis of immersion[14]. ANF appears to play a role in volume regulation due to its vasorelaxant, diuretic and natriuretic properties[11,18]. Although immersion is associated with both diuresis and natriuresis, the two events may not be interrelated. Diuresis usually manifest by 1-2 hour but natriuresis usually peaks by 4-5 hour. Moreover the difference in temporal profile of both has been re-emphasised. These observations suggest the importance of separate mechanisms of diuresis and natriuresis[11].

The present observations on hematological changes during DI are indicative of early haemodilution progressing to haemoconcentration towards the end and these findings were essentially similar to water immersion studies.

References

1. Nicogossian AE, Parker JF : Simulations and analogs of weightlessness in : Space Physiology and Medicine, NASA SP 477. Editors : Nicogossian AE, Parker JF, Washington DC, US Govt printing office 1982; 220-224.

2. Shulzenko EB, Vil-Vilyams IF : Possibility of long term water immersion by the method of Dry Immersion. Kosm Biol Aviakoso Med 1976; 2 : 82-84.

3. Shulzenko EB, Panfilov VE, Gogolev KI : Comparison of physiological effects of Head-down tilt and immersion on the human body. Aviat Space Environ Med 1979; 50 : 1020-1022.

4. Nair PR, Baboo NS : The design and development of a dry flotation facility to simulate microgravity condition at ground level. Ind J Aerospace Med 1991; 35 : 11-13.

5. Greenleaf JE, Morse JJ, Barnes PR et al : Hypovolemia and plasma vasopressin response during water immersion in man. J Appl Physiol 1983; 55 : 1688-1693.

6. Harrison H, Michael: Effects of thermal stress and exercise on blood volume. Physiological Reviews 1985; 65 : 149-203.

7. McCally M : Plasma volume response to water immersion, implication for space flights. Aerospace Med 1964; 35: 130-132.

8. Khosala SS, Dubois AB : Osmoregulation and interstitial fluid pressure changes in human during water immersion. J Appl Physiol 1981 ; 51 : 686-692.

9. Greenleaf JE, Shvartz E, Keil LC : Haemodilution, vasopressin supression, and diuresis

during water immersion in man. Aviat Space Environ Med 1981; 52 : 329-336.

10. Linnarsson D, Tender B, Eiken O : Effects of gravity on the fluid balance and distribution in man. Physiologist 1985; 28 : S28-S29.

11. Epstein M : Renal effects of head out water immersion in man, implication for understanding of volume homeostatis. Physiol Rev 1978; 58 : 529-581.

12. Greenleaf JE, Shvartz E, Kravik S : Fluid shifts and endocrine responses during chair rest and water immersion in man J Appl Physiol 1980; 48 : 79-88.

13. Boening D, Ulmer HV, Meier U et al : Effects of a multihour immersion on trained and untrained subjects, renal functions and plasma volume. Aerospace Med 1972; 43 : 300-305.

14. Greenleaf JE : Physiological responses to prolonged bed rest and fluid Immesion in man. J Appl Physiol 1984; 57 : 619-633.

15. Arborelius M, Balldin VL, Lila B et al : Haemodynamic changes in man during water immersion with head above water. Aerospce Med 1972 : 43 : 592-598.

16. Gauer OH, Henry JP : Circulatory basis of fluid volume control. Physiol Rev 1963 : 43 : 423-481.

17. Graveline DE, McCally M : Body fluid distribution : Implications for zero gravity. Aerospace Med 1964; 35 : 130-132.

18. Gharib C, Ganqualine G, Geelen G et al : Volume regulating hormones during simulated weightlessness. Physiologist 1985; 28 : S30-S33.