The Design and Development of a Dry Floatation Facility to Simulate Microgravity Condition at Ground Level

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The condition of weightlessness remains one of the primary environmental concerns of space flight. A variety of ground based studies using analogues of weightlessness have been carried out to investigate the effects of weightlessness on man. Although none of these methods simulate true weightlessness or 'Zero gravity', valuable information can still be obtained from these studies of simulated microgravity on human physiology. One such analogue is the method of dry floatation or dry immersion, and the present endeavour is to design a floatation facility where volunteers would be 'immersed dry' (protected from direct contact with water). This system consists of a double walled mild steel tank (2.4m x 1.2m x 1.1m) filled with water at about 33°C-34°C. In the middle of the tank, there is a hydraulic lift which supports a thin water proof sheet (High density Polyurethane), spread over the filled tank. The subject can be positioned supine inside the water tank on top of the sieved platform with the plastic sheet in between. The board is then lowered hydraulically, so that the subject will be immersed 'dry' in the tank. On completion of the exposure protocol, the platform can be raised to support the subject from below so as to enable him to step out smoothly. The details of design and development of this dry water immersion facility are described in this paper.

Key Words : Dry floatation, microgravity simulation

Introduction

The condition of weightlessness remains one of the primary environmental concerns of space[1-4]. The various physiological changes that occur in the weightlessness environment of space craft are seen to be more in the nature of adaptive changes in the human organism to the new environment[1-4]. However,the mechanisms underlying these physiological adaptive changes are still not fully understood.

Since it is difficult to carry out an indepth study of these changes during a space flight on human subjects, a variety of ground based studies using analogues of weightlessness have been used to investigate this aspect[3,5].

Among the first of the techniques of simulating weightlessness was based on the Keplerian trajectory model[6]. This was followed by water immersion studies[7], horizontal bed rest, chair rest and head down tilt[3,8]. A modification of the water immersion model was described by Shulzenko et al in 1976. They called it dry floatation or dry immersion[9]. This is essentially similar to the method of water immersion. However, here the subject is protected from direct contact with water by a thin plastic sheet. This is probably the ideal analogue of weightlessness as it does not have the problems of maintenance of hygiene, and development of skin maceration observed during water immersion, nor the subjective discomfort of head down tilt[3,5].

Although none of these methods simulate true weightlessness or zero G, valuable information can still be obtained from these studies to understand the underlying mechanisms of adaptation/readaptation and thereby in the development of countermeasures[3,5].

The Principle of Dry water Immersion.

A body that floats in water can be considered to be apparently weightless as floatation occurs only when the weight of the body is opposed by an equal force of buoyancy (Fb)[10]. A spring balance, if used to weigh the body now, will register a 'zero' reading[11].

Furthermore, in nonrigid bodies like that of the human being, weight is produced by the deformation caused by the resultant of forces acting on the body or F(e)[7,12]. This deformation is detected by the mechanoreceptors, especially those of the skin, and weight is appreciated.

On dry water immersion, mechanoreceptor cues are eliminated since the water is evenly distributed over the entire surface of the skin, and

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no deformation occurs[7]. In other words, no F(e) is acting on the body, thus no weight is felt.

During dry immersion, the hydrostatic pressure gradient generated within the vertical blood columns by gravity is eliminated on account of the position of the subject as well as the counter pressure of water all around[13,14]. This effects an immediate shift of intravascular fluid from the lower part of the body to the thorax and head, followed by a slower shift of interstitial fluid into the blood vessels of the lower limb on account of a decrease in the high hydrostatic pressure difference across the capillaries of the lower limb[13-16]. This central fluid shift causes a sustained increase in central blood volume, and in the central venous pressure for a short duration. This in turn compels various compensatory mechanisms to reduce extracellular fluid volume. The adaptation is achieved primarily by a diuresis which reduces the plasma volume because of decrease in ADH, Aldosterone, and Renin-Angiotensin activity. There is also a reduction in sympathetic nervous activity[11,13,14,15,17].

Description of the Dry Water Immersion Facility

The immersion facility consists of a main immersion tank and auxiliary heating tank. The tanks are of equal size, 2.2m x 1.2m x 1.1m made of mild steel 3.15mm thick, double walled with a 50mm gap between the layers. This is filled with thermally insulated material. The deadweight of each tank is 750 Kg. and it can hold 2500 L of water (Fig).

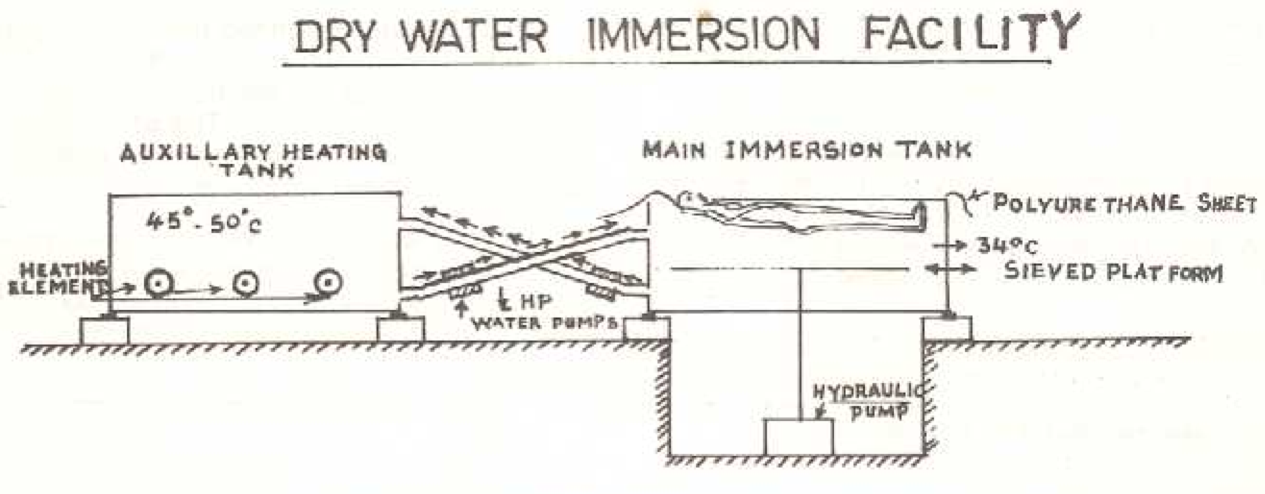
Inside the main tank is a sieved platform made of mild steel (1.8m x 0.6m x 0.05m). This is connected to a hydraulic lift with a stroke length of 1m by means of which this platform can be raised or lowered. The bore of the hydraulic lift passes down through the middle of the tank to the hydraulic pump positioned below the tank.

Both the tanks are placed on a masonry structure 0.5m above the floor, while the hydraulic pump is positioned in a special pit below the main tank 1m below floor level. Both the tanks are connected to the main water source by 11mm G.I. pipes.

The auxiliary heating tank is connected to the main immersion tank by two G.I. pipes 22 mm in diameter, to pump heated water to the main tank and second one to return colder water to the heating tank. This is done by two half horse power pumps which are simultaneously operated so that during this transfer of water,volume change is minimal in the main tank.

Heating is done by means of 6 heating elements of 2.5 KW incorporated into auxiliary tank, 3 to each side. The amount of heating can be controlled from the main control panel where the temperature of the water in each tank is sensed by thermal sensors and digitally displayed. The water temperature in the immersion tank is maintained at a temperature 32-34°C (close to the average mean skin temperature).

Before starting the experiment, water is filled in both the tanks upto 15 cm from the top. The platform is also raised to this level. Then the heating elements are switched on from the main control panel till water temperature in the heating tank reaches 50°C. Now the heaters are switched



off and the two water pumps are started to transfer the heated water into the main tank, while simultaneously pumping cooler water back to the heating tank. This is continued till the water temperature in the main immersion tank reads 34°C. At this point, the water pumps are switched off and a thin water proof sheet made of high density polyurethane (5.5m x 4.3m and 400 microns thick) is spread over the main immersion tank so as to completely and evenly cover it. The subject is positioned supine inside the immersion tank, on top of the sieved platform with the plastic sheet in between. The platform is then lowered hydraulically, and the subject thus floats in the tank, without coming in contact with the water. Heater water from the auxiliary tank (45-50°) is circulated whenever required through the floatation tank so as to maintain that tank water temperature at about 34°C.

On completion of the exposure protocol, the platform is raised again to support the subject from below so as to enable him to step out smoothly.

Certain safety and operational features of this facility are :-

(a) All the heating is done in the auxiliary tank to maintain electrical isolation of the subject in the main immersion tank.

(b) The platform is sieved so that there is minimum resistance and turbulance during its raising and lowering.

(c) The tanks are double walled and filled with thermally insulating material to reduce heat loss and conserve power.

(d) The uppermost level of the platform is kept 6 inches from the top of the tank so that water displaced during immersion does not spill out.

(e) There is a provision to lower the platform mechanically too, so that in the event of power failure the experiment is not jeopardised.

This facility has been successfully put into use in order to simulate Zero G conditions in this laboratory.

REFERENCES

1. Berry CA : "Apollo 7 to 11" : Medical concerns and results. NASA TM X - 58034, 1969.

2. Johnson RS, Dietlein LF : Biomedical results from skylab; NASA SP-377, 1977.

3. Niogossian A, Parker JF Jr : Space Physiology and Medicine; NASA SP-447, 1982.

4. Vorobyov EI, Grazenko OG, Genin AM, Egorov AP : Medical results of salyut - 6 manned spaceflight. Aviat Space Environ Med; 54(s) : S 31-S-40,1983.

5. Hinghter - Szalkey H : Tilt table and related studies. Zero 'G' New York Simulation for ground based studies in human physiology with emphasis on the cardiovascular and body fluid system. ESA-SP 180; 81-100,1982.

6. Haber F, Haber H : Possible methods of producing the gravity free state for medical research. J Av Med 1950; 21 : 395-400.

7. Knight LA : An approach to the physiologic simulation of the null gravity state. J Aviat Med 1958; 29 : 283-286.

8. Kakurin LI, Lobachik VI, Mikhnailov VM et al : Antiorthostatic hypokinesia as a method of weightlessness simulation. Aviat Space Environ Med 1976; 47 : 1083-1086.

9. Shulzenko EB, Vil-Vilyams IF : Possibility of prolonged immersion in water using the method of 'dry' immersion. Kosm. Biol Aviakosm Medit 1976; 2 : 82-84.

10 Halliday D, Resnick R : Fundamentals of Physics 3rd edn; 1988 : Johnwilly and Sons New York.

11. Nixon JV, Murray RG, Bryant C et. al. : Early cardiovascular adaptation to simulated zero gravity. J Appl Physiol 1979; 46 : 541-548.

12. Haber H : Gravity, Inertia and weight. Physics and medicine of the upper atmosphere 1952; 123-129.

13. Epstein M.: Renal effects on head-out water immersion in man, implication for understanding of volume homeostasis. Physiol. Rev. 1970; 58 : 529-595.

14. Greenleaf JE : Physiological responses to prolonged bedrest and fluid immersion in men. J. Appl. Physiol. 1984; 57 : 619-633.

15. Greenleaf JE, Sharvtz E, Keil LC : Haemodilution, vasopressin suppression and diuresis during water immersion in man. Aviat. Space Environ. Med. 1981; 52(6) : 329-336.

16. Tomeselli CM, Kenney RA, Frey MB, et al : Cardiovascular dynamics during the initial period of head down tilt. Aviat. Space Environ. Med. 1987; 58 : 3-8.

17. Gauer O, Henry JP, Behn C : Regulation of extracellular fluid volume. Ann Rev. Physiol. 1970; 32 : 547-595.