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EFFECT ON PHYSIOLOGICAL SYSTEM AT ZERO GRAVITY

G. Baby[1*], D. Vijaya Lakshmi, Abdul Saleem, J.N. Suresh Kumar.

Research scholar, B. Pharmacy, Narasaraopeta Institute of Pharmaceutical Sciences, Narasaraopet.

Research Scholar, B. Pharmacy, Narasaraopeta Institute of Pharmaceutical Sciences, Narasaraopet.

Research Scholar, VMRF, Saleem, Department of Pharmacology, Narasaraopeta Institute of Pharmaceutical Sciences, Narasaraopet.

Professor and Principal, Department of Pharmaceutics, Narasaraopet Institute of Pharmaceutical Sciences, Narasaraopet, Kottapakonda Road, Guntur district.

ABSTRACT

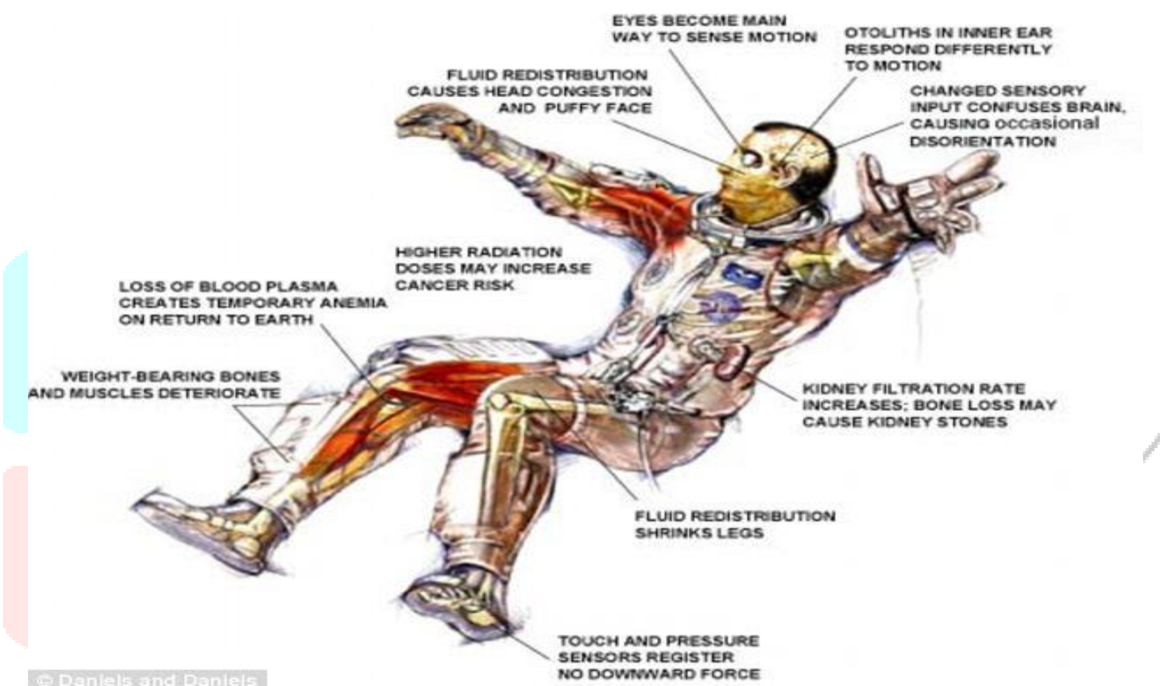
The effect of micro gravity conditions on neurovestibular, cardiovascular, musculoskeletal, bone metabolic, respiratory, circulatory, occular, urinary, reproductive system are described. We discuss "space motion sicknesses", sensory motor co-ordination disorders, cardiovascular deconditioning, muscular atrophy, bone loss, anemia, diuresis, including their causes and mechanisms. In addition to the previously described deconditioning, new problems related to microgravity, space flight- associated neuro ocular syndrome (SANS), structural changes of the brain by magnetic resonance imaging (MRI) are also explained. Our countermeasure, artificial gravity produced by short- arm centrifuge with ergometric exercise, is also described in detail, and we confirmed this system to be effective in preventing the above mentioned deconditioning caused by microgravity exposure.

KEY WORDS

Microgravity, neurovestibular, Ocular, Respiratory, cardiovascular, musculoskeletal, bone metabolism, circulatory, Immune system, Bed rest.

INTRODUCTION

Long stays in weightlessness take a toll on the human body, as the muscle atrophy, bones lose minerals, and a new set of stimuli imposes novel challenges on the vestibular and cardiovascular system. In space flight astronauts face three periods of physiological adaptations induced by changing gravity:1) changes upon entry to microgravity (initial adaptations), 2) changes after prolonged exposure to microgravity, and 3) re adaptation to G1 gravity on earth after returning from space. Body systems influenced by microgravity are the neurovestibular, cardiovascular, musculoskeletal, bone metabolic, and immune-hematological systems. The changes associated with these systems occur during the adaptation phases outlined above. We will briefly discuss each of these body systems.



Effect on Neurovestibular system:

- The vestibular organs include the otolith organs and semicircular canals. The otolith organs, saccules (sagittal direction) and utriculi (horizontal direction), sense linear acceleration.
- The semicircular canals, anterior, posterior and horizontal, detect angular velocity of the head. Vestibular organs in the inner ear detect and measure linear and angular acceleration.
- These responses already complex set of signals are further integrated with visual and proprioceptive inputs.
- Although sensory misinterpretation may play a role in space motion sickness, its exact mechanism remains unknown.
- There are, however, several hypothesis :1) sensory conflict, 2) fluid shift 3) otolith asymmetry and 4) orientation adaptation.
- Exposure to microgravity alters some of these input signals, leading to misinterpretation and inadequate responses by the brain. This may cause vertigo, nausea, vomiting, appetite loss, headache, pallor, etc.
- As the symptoms are like those motion sicknesses, this set of symptoms is termed “space motion sicknesses”, but unlike conventional motion sicknesses, anti-emetic drugs can not suppress the symptoms of space motion sicknesses.
- Approximately 60-80% of astronauts develop the symptoms with in 2 or 3 days after launch.

- The cephalad fluid shift leads to visible puffiness in the face & is thought to increase the intracranial pressure, the cerebrospinal fluid pressure, or the inner ear fluid pressure altering the response properties of the vestibular receptors and inducing space motion sicknesses.
- Neuroplastic changes in the central nervous system and concluded that the cerebellum, cortical motor areas, and vestibular-related pathways are highly involved, demonstrating that these brain regions are indeed affected by actual and simulated spaceflight. Structural studies are now in progress, and functional relationships are under investigation. Long-term studies will be necessary to clarify the mechanism.
- In positive gravity leads to reduction in cerebral blood flow, if the angular acceleration is more than +5g there would be "blackout"- total loss of consciousness.
- In negative gravity leads to in foot to head direction blood is moves towards head, rise in cerebral arterial pressure.

Effect on eye:

- First the person experiences a temporary loss of vision and then at higher g-forces losses consciousness. Eyes can see which way is up and down inside the space shuttle.
- The eye is a small organ whose function relies on the co- ordinated operation of its optical, vascular, epithelial, and neural components.
- In space, the fluid redistribution caused by microgravity affects the blood supply to the eye with an impact that depends on specific facets of its vascularization.
- The evolution of initial fluid redistribution into long- lasting effects on aye anatomy and function depends on SF duration.
- Blood supply to the retina and posterior pole of the eye is via the ciliary arteries and the central retinal branches of internal carotid artery, although variations are frequent.
- The retinal has an oxygen consumption rate per unit weight higher than the brain, consistent with the high metabolic rate of photoreceptors.
- Reduced to oxygen supply to retina. The narrowing of the field of loss of peripheral vision and loss of color variation is called "grayout". Hyperemia (red out) in negative gravity.
- Enter the microgravity due to cosmic radiation will damage to the eyes, and some cataract problems, visual perception will be occur.

Effect on respiratory system:

- Gravity causes uneven ventilation in the lung through the deformation of lung tissue. So, called slinky effect.
- Uneven perfusion through a combination of the slinky effect of pulmonary perfusion.
- Both ventilation and perfusion exhibit persisting heterogeneity in microgravity, indicating important other mechanism.
- Weightlessness decreases abdominal girth, increase abdominal compliance, and substantially increase the abdominal contribution to tidal volume during resting breathing.
- Despite these changes, there does not appear to be any alteration in the temporal pattern of breathing.
- Microgravity causes decrease in lung and chest wall recoil pressure as it removes most of distortion of lung parenchyma and thorax induced by changing gravity field.
- In space there is very little breathable oxygen. This prevents the oxygen atoms from joining together to form oxygen molecules.

- The changes in lung function when gravity is removed, the lung continues to function well in weightlessness.
- Slight increase in respiratory frequency and physiological dead space thanks to homogeneous blood redistribution in lung vessels.
- Maximum expiratory pressure at total lung volume was significantly reduced at 2-4 months.
- Changes in thorax wall and respiratory mechanics are among the first aspect to address when considering respiration in space.
- In microgravity, the contribution of abdomen to the tidal volume increases, while rib cage expansion is reduced.
- Studies in the 1990's suggested that microgravity decreased vital capacity (VC), and forced vitality capacity (FVC), and peak inspiratory and expiratory flows.
- The authors proposed that microgravity could weaken respiratory muscles.

Effect on cardiovascular system:

- The changes in cardiovascular system begin solely with the fluid shift associated with microgravity, followed by- decreased circulatory blood volume, cardiac size, aerobic capacity, most prominent symptom, post flight orthostatic intolerance.
- These symptoms are genetically known as cardiovascular deconditioning.
- Heart will shrink in size. Fast fluid shift from the intravascular to interstitial spaces as a result of lower transmural pressure after reduced compression of all tissues by gravitational force.
- Reduced blood volume. One way to deal with fluid loss in space is with a device called lower body negative pressure.
- In positive gravitation leads to cardiac output and blood pressure is diminished.
- In negative gravitational leads to increase in central blood volume.
- The change in blood volume affects your heart too- if you have less blood your heart does not need to pumps as hard. Because it no longer has to work as hard, your heart will shrink in size.
- A negative balance of decreased fluid intake and smaller reduction of urine output.
- Fast fluid shifts from the intravascular.
- The arterial blood pressure slightly decreases compared with the preflight level. Compared with "space motion sickness," cardiovascular and fluid balance adaptation is gradual. The symptoms appear in 3–5 days and disappear after 1–2 weeks, causing facial edema, nasal stiffness, heavy headedness, papilledema, or jugular vein dilatation. These symptoms upon

Effect on circulatory system:

- Fluids shift is also happen in microgravity. The circulatory blood volume is 5L on average and contains plasma & cellular components, including erythrocytes, leukocytes (neutrophils, eosinophils, basophils, and lymphocytes), and platelets.
- Among them reduction in cellular components especially erythrocytes (RBC), is associated with anemia, whereas the function of leukocytes is related to immunological response.
- The true effect of microgravity can be measured through the total RBC count calculated from the hematocrit & plasma volume measurements.
- On earth gravity pulls on your blood shift from legs to your chest and head causing legs shrink in size.
- Anemia, the decrease of red blood is observed within four days of space light.
- Another problem blood is pooled in lower extremities in positive 'g' of need to foot direction.
- Decreased plasma volume.

- Additional symptoms include fluid redistribution ("moon face" appearance in pictures of astronaut's experience in weightlessness), loss of body mass, nasal congestion, sleep disturbance, and excess flatulence.
- Deceased production of red blood cells, changes in fluid distribution.
- G-force training and a G-suit which constricts the body to keep more blood in the head can mitigate the effects.

Effect on immune system: -

- Since the Apollo missions started almost 60 years ago, scientists have been monitoring space travel's negative effects on health.
- A new study concludes that reduced gravity makes the immune system malfunction, reducing the immune response
- Recent studies confirmed dysregulation of the immunological response in humans and the reactivation of latent herpes virus, which persisted for the duration of a 6-month orbital spaceflight.
- Blood samples from ISS crew members demonstrated that long exposure to microgravity reduced their T lymphocyte counts, suggesting the attenuation of cytotoxic function and viral reactivation in the space environment.
- As the immune system is highly sensitive to different types of stressors, including psychological, physical, and local environmental stressors (e.g., oxidative and radiation exposure), exposure to the space environment suppresses T helper cells, which leads to susceptibility to viruses.
- The mechanism underlying anemia was also confirmed by measuring the erythropoietin (EPO) level [77]. Radioimmunoassay revealed that the EPO level decreases after 24 hours of flight and is reduced by 30–40% on the third day compared with preflight levels. This low secretion of EPO will inhibit RBC maturation and cause hemolysis due to suppressed erythropoiesis.
- Radiation can penetrate living tissue and cause both short and long-term damage to the bone marrow stem cells which create the blood and immune systems.
- In particular, it causes 'chromosomal aberrations' in lymphocytes. As these cells are central to the immune system, any damage weakens the immune system, which means that in addition to increased vulnerability to new exposures, viruses already present in the body—which would normally be suppressed—become active.
- In space, T-cells (a form of lymphocyte) are less able to reproduce properly, and the T-cells that do reproduce are less able to fight off infection. Over time immunodeficiency results in the rapid spread of infection among crew members, especially in the confined areas of space flight systems.

Effect on skeletal system:

- The main problem of skeletal system is bone calcium loss during microgravity. Bones become fragile during microgravity exposure, which can harm an astronaut even after returning to earth.
- Moreover, the risk renal stones is high during long term mission due to hypercalcemia.
- Calcium plays an essential role in bone structure, contraction of skeletal and cardiac muscles, neural transmission, blood coagulation, cell permeability, and hormonal signaling.
- The serum ca+2 level is well maintained at 8.4-10.2mg/dL.
- Ca+2 is absorbed from the small intestine (300mg/day), into the blood, deposited in the bone (500mg/day), and excreted from the kidneys (150mg/day) or into feces.

- Osteoblasts and osteoclasts are functionally closely related, as is the balance between bone formation and bone resorption. Thus, insufficient bone formation compared with bone resorption observed in spaceflight reduces the bone mass and bone strength, leading to fractures
- Bone loss occurs in the weight less.
- The loss of minerals, including calcium and phosphorus from the bone. This results in a loss of bone density is called “bone demineralization”.
- Loss of muscle tone; loss of muscle mass, aerobic capacity decreases. This is due to fact that gravity does not oppose the muscle contraction.
- Degeneration of the musculoskeletal system.
- In this section, the influence of gravity on bone structure and hormones on bone formation and absorption are described.

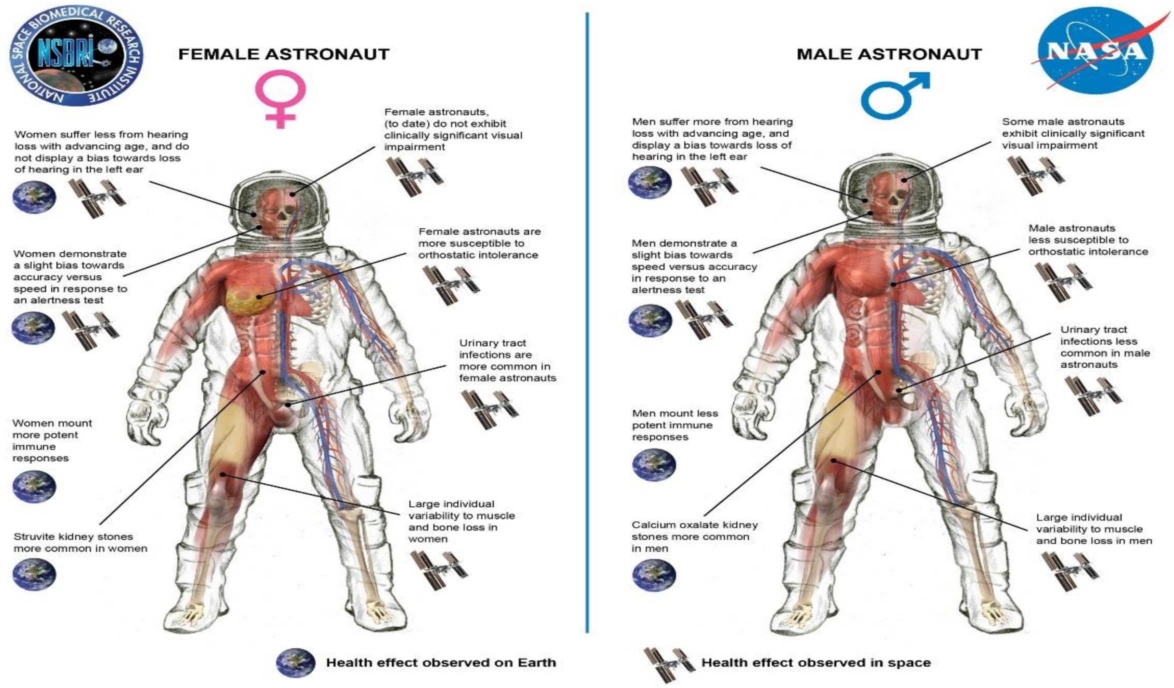
Effect on urinary system:

- Previous data have demonstrated that human exposure to microgravity increase the risk of renal (kidney stone) development during and immediate after space light.
- In flight changes previously observed include decreased urine volume and increased urinary excretion of calcium, phosphate and sodium.
- Renal stones is high during long term machines of hypercalcemia.
- Decreased fluid intake and smaller reduction of urine output.
- Body senses an overabundance of fluids in the chest and head area and sends a message to the kidney, to eliminate the excess fluid by producing more urine.
- Do not feel thirsty and become dehydrated.
- The result is up to 22% loss of blood volume. Because of excessive of a fluid by the kidneys, there is also decrease of formation of red blood cells.
- Kidney filtration rate increases bone loss may cause kidney stones.
- GFR number is very low, kidney are not working. The earlier kidney disease is detected.
- Still, kidney perfusion has been found normal in space, along with increased diuresis and natriuretic. Imbalance fluid distribution.

Effect on reproductive system:-

- The near-zero gravity of Earth orbit may do serious harm to the male and female reproductive systems, the University of Kansas Medical Center biologist has discovered. Sperm counts drop. Egg-producing ovary cells waste away.
- Although his results may explain why sperm move faster in space, they don’t necessarily imply that fertilization will be easier.
- It is assumed, but to a large extent unproven, that women’s responses to space flight are similar to men’s although the magnitude of women’s responses compared to men’s is not so well known.
- In female reproductive system cause gonads susceptible to cancer and genetic germline mutations.
- Some sex- based difference in response to actual space flight are, however, fairly well accepted; men’s post- flight orthostatic tolerance is not as degraded as women’s.
- Sex based difference in response to stimulations of partial gravity environment come mostly from head-down bed rest and water immersion studies.
- Men and women Earth bound tendency of men towards Sympathetic dominance and women’s tendency towards parasympathetic dominance over heart rate control remained the same after 60 days of bed rest.

- Men and women use different Blood pressure regulation strategies to respond to standing in earth gravity after being exposed to hypergravity.
- Men's starts from a lower blood pressure finally reaching their pre syncopal end point, while women maintain the same Blood pressure upto presyncope.



Reproduction in space is a long-term goal that people would want to meet," Ruth Globus, rodent research project scientist at NASA's Ames Research Center, told NBC News. "Even if people were to say, 'We don't care about the long term, we only care about now,' it's important to understand what's happening to the ovaries and the testes [in the space environment], and the subsequent changes that may occur.

Conclusion: -

Several deconditioning States in the neurovestibular, cardiovascular, occular musculoskeletal, bone metabolic, hematological & immunological and central nervous system have been documented and efforts to ameliorate the symptoms have been made. On Earth, aging affects the cardiovascular, musculoskeletal, nervous, gastrointestinal, urinary and neuroendocrine systems (Boss and with immune system impairment and an enhanced inflammatory activity. Remarkably, these changes occur in space 10-fold faster than on Earth allowing scientists to speculate that the astronauts may be an appropriate model for exploring the mechanisms of aging. Frame work for understanding how external and internal mechanical forces influence the living organism at molecular and cellular leves.

From the analysis of published data, it appears that a reductionist approach (assuming one or another main challenging factor) cannot easily explain the impact of long-term exposure to SF conditions. Indeed, this review shows that the independent actions of either body fluid redistribution or radiation exposure may not account for the organism response to long-term SF. In addition, the role of hormonal stress response to weightlessness may contribute to shaping the adaptation of the human body to space although this aspect has remained largely unexplored. Indeed, increased cortisol levels during SF are expected to affect kidney operation, bone resorption, immunity, muscle loss, glycaemic control, endothelial response and may contribute to the discrepancies observed between short-and long-term SF and to the inter-individual variability as well. Analysis of SF impact on health may benefit aging people on Earth. Aging is a progressive, time-dependent physiological deterioration of the homeostatic response and adaptation to the external environment that makes the individual fragile and more vulnerable to diseases.

Historically, Space medicine examined early adaptation to microgravity and early readaptation to terrestrial G1 state under this scenario, short exposure to microgravity is permitted, but longer adaptation will be necessary with this philosophy, the authors believe that the humans will achieve safe and comfortable space flight without deconditioning.

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