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ADAPTING AYURVEDA FOR SPACE EXPLORATION: WELLNESS STRATEGIES BEYOND EARTH

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ABSTRACT: Introduction: The space environment induces distinct modifications in astronaut physiology that necessitate the attention of medical professionals and researchers. These alterations stem from various space related factors including radiation, disrupted sleep-wake cycles and notably the absence of Earth's gravitational pull, which has traditionally been crucial for establishing normal bodily functions and balance. It has been noted that exposure to microgravity leads to a dysregulated human immune system at the cellular level, potentially posing health risks for astronauts. **Methods:** The completion of this study involved consolidating information from classical Ayurvedic literatures, academic research papers, guidelines, as well as searching databases such as PubMed and MedLine. **Results and Discussion:** Radioprotective agents encompass substances such as antioxidants and similar compounds containing sulfhydryl groups along with adaptogens, are agents that enhance resistance to radiation. Typically derived from natural sources, these biological protectors defend against mild ionizing radiation by regulating immune responses and enhancing the body's own antioxidant mechanisms, thus enhancing overall resistance in biological systems. *Ayurvedic* medicinal plants exhibit a promising ability to modulate the immune system, offering advantages over other system medications by minimizing side effects. **Conclusion:** This review provides an overview of *Ayurvedic* remedies proposed to counteract the effects of the space environment on astronauts physiology, with particular focus on microgravity and space radiation. It proposes additional evidence driven investigation into diverse medicinal plants to tackle therapeutic obstacles and enhance the utilization of India's traditional medicinal wealth to bolster health and combat severe illnesses.

INTRODUCTION: It has been evident that astronauts encounter physiological alterations in the unfamiliar and demanding conditions of space. Microgravity, characterized by a negligible gravitational force experienced during free fall is often described as weightlessness due to the minimal gravitational pull.

Prolonged exposure to weightlessness leads to notable detrimental effects, such as muscle wasting and deterioration of bone density.

The Challenges of Space Exploration: Living in microgravity environment impacts significant effects on the body systems such as the cardiovascular system slows down, immune system changes, musculoskeletal system deteriorates and the sensory motor dysregulate. These systems effects cause disorders in the body of the astronaut such as decreased bone formation and bone mass, decreased number of T lymphocytes, shift in body fluids, loss of balance and reduced heart rate. Space radiation stands out as a primary concern for

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human missions to Mars, widely recognized as one of the most perilous hazards. There is scientific apprehension that prolonged space travel could impede the body's natural defences against diseases. To address this concern, deep space vehicles are equipped with substantial protective shielding, monitoring systems, and alert mechanisms.

Physiological Alterations in Astronauts: Space radiation affects the circulatory, cardiovascular, musculoskeletal, immunological and gastro intestinal systems causing disorders such as increase of blood in the upper body, decreased heart rate, bone demineralization, muscle atrophy, immune dysregulation, change in appetite and nausea. Some solutions to the effects of microgravity and space radiation include exercise, use of dietary supplement with calcium and vitamin D and K, Health Stabilization Program, use of buckles and system straps, use of Lower Body Negative Pressure, simulation of earth gravity in spacecraft and use of anti-nauseate ¹.

The Role of Ayurveda in Space Medicine: In conclusion with special consideration to microgravity and space radiations knowing about the dangers of the space environment on seeks to better understand the physiological challenges and to use reviewed solutions to them are documented in this article along with comprehensive overview of *Ayurvedic* medications and strategies as a holistic approach to managing these conditions, potentially serving as a significant advancement in addressing the physiological changes induced by the demanding space environment.

Space Induced Health Challenges and Ayurvedic Solutions to Space-Induced Disorders:

Addressing Sleep Deprivation with Ayurveda: *Acharya Sushruta* recommends incorporating various foods such as rice, wheat, pastries made from rice flour, sugarcane juice and its derivatives, milk, and meat soups, particularly those made from burrowing animals and gallinaceous birds like roosters. The diet should primarily consist of sweet-tasting (*Madhura Rasa*) and unctuous (*Snigdha Guna*) foods. Specifically, the use of grapes, sugar, and sugarcane and its derivatives is recommended during Nighttime ². *Acharya Vagbhata* suggests incorporating various

preparations made from jaggery and recommends consuming meat soups made from animals dwelling in marshy areas and aquatic creatures such as fish. Additionally, he advises the use of black gram, paneer, and curd made from buffalo's milk to alleviate insomnia or sleep disturbances. Consumption of ghee prepared with a combination of ten vitality enhancing drugs known as *Jeevaneeya Gana*, followed by milk as a supplementary drink, is recommended ³. Furthermore, it is advised to consume alcohol brewed from rice. According to *Acharya Indu*, this specific alcoholic concoction will aid in achieving a state of intoxication. *Sura Madya* is a beverage made from the fermentation of rice flour ⁴. *Shirodhara* induces mental relaxation, leading to a harmonious balance between the mind and body. It is often likened to yogic meditation, involving the rhythmic pouring of medicated fluid over the forehead.

Combatting Bone Loss and Osteoporosis in Space: In this segment challenges comprise reduced bone formation, heightened bone resorption and diminished bone mass leading to premature onset of osteoporosis. In contemporary medical treatments interventions such as resistance exercises, dietary supplementation with calcium, amino acids, vitamins D and K and regular physical activity are employed to prevent muscle and bone deterioration ⁵. Within *Ayurveda*, bark of *Terminalia arjuna* (Roxb.) holds significant medicinal importance. Its ethanol extract comprises tannins, a glycoside which have substantial quantities of calcium carbonates and lesser amounts of aluminium and magnesium ⁶. The bark of *Arjuna* is renowned for its ability to remineralize bones and is widely utilized in the treatment of osteoporosis and other bone related conditions ⁷. To address reduced bone formation, the utilization of *Rasayana* medications targeting *AsthiDhatu*, such as *Asthishrunkhala* (*Cissus quadrangularis*) is recommended. These drugs act by enhancing metabolism and promoting the absorption of essential minerals like calcium, sulphur and strontium by osteoblasts aiding in fracture healing. Additionally, specific amino acids such as lysine facilitate calcium absorption. *Cissus* also contains Vitamin A and C, which contribute to the formation of collagen ⁸.

The impact of the alcoholic extract of *Guduchi* (*Tinospora cordifolia*) on the proliferation, differentiation, and mineralization of bone matrix was investigated using human osteoblast like cells MG-63 and primary osteoblast cells isolated from the femur of rats. The extract also elicited prostimulatory effects on osteoblasts⁹. A study revealed that *Tilataila* (sesame seed) provides 100% of the recommended daily allowance for manganese, potassium and 57%-65% of phosphorus and iron and 13%-35% for zinc, calcium, and copper, while its recommended daily intake is typically between 25 to 50 grams¹⁰. A protocol for addressing bone-related issues involves internal oleation with *Panchatikta Ghrita* (a medicated ghee) followed by enema therapy with *Panchatikta Ksheer* (a medicated milk). This protocol includes calcium containing herbal formulations like *PravalaBhasma* and *MuktaPishti Bhasma*. It is recommended to initiate measures to prevent bone fragility starting from the stage of bone marrow depletion, which precedes the onset of bone fragility (bone porosity)¹¹.

Ayurvedic Principles for Astronaut Health with Immunomodulation through Ayurvedic Herbs, Based on the Concept of Rasayana: The issues comprise a reduction in the quantity of T lymphocytes, diminished T lymphocyte responsiveness to potent activators, and changes in cytokine/chemokine activity. In contemporary management, the Health Stabilization Program aims to reduce or eliminate the risk of infectious diseases among crew members¹². In Ayurveda *Rasayana* therapy promotes nutrition by enriching the quality of *Rasa* (nutritional blood), improving digestion and metabolism (*Agni*) and enhancing the function of microcirculatory channels in the body (*Srotas*)¹³. *Rasayana* medications also exhibit antagonistic effects against oxidative stressors, which contribute to the generation of various free radicals. Their ability to counteract stress has enhanced their therapeutic significance¹⁴. Certain *Rasayana* formulations stimulate mononuclear cells to produce cytokines such as GM-CSF and IL-1 in a manner dependent on dosage and findings suggest that *Rasayana* treatments, particularly those with a *MadhurVipaka* (sweet postdigestive effect) recommended as adaptogens in *Ayurveda*, may primarily activate immune cells. Consequently, the secretion of cytokines induced

by these *Rasayana* formulations may exert effects on multiple target organs contributing to the diverse therapeutic effects attributed to these treatments¹⁵. *Rasayana* treatments have also been observed to enhance tumour cell lysis through antibody dependent complement activation¹⁶. Immune products such as various cytokines have been identified to activate the hypothalamus pituitary adrenal axis and trigger the release of corticotrophin releasing factor (CRF), leading to increased production of adrenal corticotrophic hormone and subsequently more secretion of glucocorticoids which exert an overall suppressive effect on the immune system. Stress also affects this axis, resulting in alterations in the body's immune status. *Rasayana* medications likely alleviate stress levels by modulating antioxidant levels. Thus, these *Rasayana* drugs function as potent antioxidants and neuroendocrine immunomodulators¹⁷.

Ayurvedic Approaches for the Cardiovascular Health in Space: Issues like diminished heart rate due to decreased cardiac efficiency leading to disruption of other physiological functions. Additionally, there is a reduction in diastolic pressure and post flight postural hypotension that leads to hypovolemia, results in a swollen face due to a shift in body fluids, known as moon face. In modern management, the utilization of systems involving straps and buckles to assist in maintaining an upright posture should be duly recognized, especially for addressing cardiovascular problems¹⁸. The utilization of *HridyaMahakashaya* in conjunction with *ArjunaKsheerpaka* and diverse yoga practices, along with supplementation of *Amla* (*Emblia officinale*), resulted in enhanced endothelial function, reduced oxidative stress¹⁹. Dyslipidemia is frequently cited as a risk factor for the development of heart complications such as atherosclerosis. Therefore, the utilization of *Amalaki* (*Emblia officinalis*) extract, known for its hypoglycemic properties, has shown promise. This extract has the potential to address both general and diabetic dyslipidemia by significantly reducing total cholesterol and triglyceride levels, lipid ratios, atherogenic index of plasma and the ratio of apolipoprotein B to apolipoprotein A-I in individuals with dyslipidemia²⁰. In traditional Indian medicine, *Tulsi* (*Ocimum Sanctum*) has been

recommended for its various properties including its potential as an anti-diabetic, antihypertensive, adaptogenic, antilipidemic and cardio-protective agent among others ²¹. Ingesting fresh garlic (*Allium Sativum*) may lower the chances of developing cancer and hypertension, boost immunity, and support cardiovascular wellness. It contains a range of amino acids, essential minerals and various vitamins ²².

Sensory Motor Challenges and their Ayurvedic Solutions: The challenges associated with space travel encompass issues like loss of balance, altered perception of orientation, deconditioning of posture and gait control as well as the deconditioning of motion sensors and the somatosensory system. These factors may lead to blood redistribution towards the head, resulting in altered responses of the baroreceptor, nervous, and endocrine systems. In modern medicine, the use of antihistamine promethazine can help prevent or treat symptoms such as nausea, vomiting, motion sickness, and allergies. Additionally, considering the treatment of nutritional deficiencies (*DhatukshayaSantarpana*), *BaladiKhseeraBasti*, a modified form of *YapanaBasti* (enema for sustaining health), can be explored. In *Ayurveda*, the brain is regarded as a form of *MajjadharaKala* ²³. A slight adjustment was made to the *Basti* procedure, wherein goat femur bone marrow was utilized to obtain *Majja* (long bone marrow). Unsteadiness and blurred vision are symptoms associated with *MajjaPradosajaVikaras*, which are diseases caused by the vitiation of the *MajjaDhatu* ²⁴.

For conditions affecting the nervous system (*Majjagata* diseases), bitter (*Tiktadi*) and sweet (*Madhura*) drugs are recommended. Bitter drugs are administered in the form of *Mahapanchatiktaghrita* ²⁵. Oxidative stress is significantly involved in the development of degenerative brain disorders that lead to gait imbalance ²⁶. Thermal therapy is recognized for its ability to improve antioxidant functions, including the activities of superoxide dismutase ²⁷. Therefore, the *Svedana* procedure might have facilitated a comparable effect. Studies have demonstrated that *Shirodhara* has anxiolytic, sympatholytic, and immunopotentiating effects on patients with anxiety ²⁸. *Bala* is also the chief ingredient of *Dhanvantaramtailam* which reported improvement

in the mobility, as assessed by timed up and go (TUG) test in older people, after treatment with a polyherbal formulation containing *Ashwagandha* and *Bala* ²⁹.

Gastrointestinal Health and Diet Recommendations as Per Ayurveda: The issues encompass alterations in appetite, characterized by significant changes in eating habits, either as an increase or decrease in appetite. *Triphala* demonstrates antibacterial effects against various types of bacteria, including both Gram-positive and Gram-negative strains. For instance, it is effective against *Streptococcus mutans*, a Gram-positive, anaerobic bacterium commonly present between teeth or in deep crevices on tooth occlusal surfaces, as well as *Helicobacter Pylori*, which is the primary cause of inflammation in the gastric mucosa ³⁰. The potential modulation of gut microbiota by *Triphala* extracts could introduce a novel approach in the creation of functional foods or nutraceuticals, offering an effective means of replenishing the gut microbiome in individuals with compromised lower gastrointestinal function ³¹.

Ayurvedic Solutions for the wound Healing in Space: Issues like impaired matrix formation is their. In lieu of contemporary treatments, there is a broad and potent *Ayurvedic* formulation available, such as *Triphala* (a combination of three fruits: *Haritaki* [*Terminalia chebula* Retz.], *Vibhitaki* [*Terminalia bellirica* Roxb.], and *Amalaki* [*Emblia officinalis* Gaertn.]) in equal parts, *Lodhra* (*Symplocos racemosa* Roxb.), *Mundi* (*Sphaeranthus indicus* Linn.), and the bark of *Dhava* (*Anogeissus latifolia* Wall.), which can facilitate wound healing in a simple and effective manner. The wound heals rapidly when dusted with a powder comprising the barks of *Arjuna* (*Terminalia arjuna*), *Udumbara* (*Ficus racemosa* Linn.), *Ashvattha* (*F. religiosa*), *Lodhra* (*S. racemosa*), *Jambu* (*Syzygium cuminii* Linn.), and *Katphala* (*Myrica nagi* Hook.f.) ³².

DISCUSSION:

Modern Space Medication Solutions: Astronauts face significant physiological changes due to the extreme conditions of space travel, including exposure to microgravity and space radiation. Microgravity induces muscle wasting, bone density loss, cardiovascular deconditioning, immune

suppression, and sensory-motor dysregulation. Prolonged weightlessness results in reduced bone formation, T-lymphocyte decline, fluid shifts, and balance disorders. Space radiation further compromises circulatory, musculoskeletal, and gastrointestinal systems, leading to bone demineralization, muscle atrophy, immune dysregulation, and altered appetite. To counter these effects, contemporary solutions include exercise, dietary supplements with calcium, vitamins D and K, Lower Body Negative Pressure, and anti-nauseate medications.

Potential of Ayurveda to Complement Existing Treatments: Ayurveda offers holistic solutions to manage space-induced disorders. For sleep deprivation, it recommends *Madhura Rasa* (sweet-tasting) and *Snigdha Guna* (unctuous) foods, *Shirodhara* therapy, and specific herbal preparations. To address bone loss, Ayurvedic herbs like *Arjuna* (*Terminalia arjuna*), *Asthishrunkhala* (*Cissus quadrangularis*), and *Guduchi* (*Tinospora cordifolia*) promote bone remineralization. Immunomodulation is achieved through *Rasayana* therapy, which enhances immune function and reduces oxidative stress.

Cardiovascular issues are managed with *Arjuna Ksheerpaka* and *Hridya Mahakashaya*, while gastrointestinal disorders benefit from *Triphala's* antibacterial and gut-modulating properties. Sensory-motor challenges are alleviated with *Baladi Ksheera Basti* and *Majja* therapy for nervous system balance. Wound healing is

enhanced using *Ayurvedic* herbs like *Triphala*, *Lodhra*, and *Dhava* bark.

Need for Evidence-based Studies in Space Health: Integrating *Ayurvedic* strategies with modern interventions offers a comprehensive approach to mitigating space-induced physiological challenges along the side further evidence based studies must be enhanced to highlighten *Ayurveda's* potential as a complementary system in space medicine.

CONCLUSION: The concept of *Rasayana* in *Ayurveda*, focusing on principles and techniques of drug formulation, particularly *Vyadhi-kshamatva*, which parallels the concept of immunity. The fundamental principles of *Rasayana* bear resemblance to contemporary scientific notions of immunomodulation. *Rasayana* Therapy aims to forestall aging and maintain optimal bodily function by rejuvenating the body's systems, enhancing the strength of *Dhatus* (bodily tissues) and *Srotasas* (body channels), and preserving the balance of *Tridosha* (the three fundamental elements of Ayurvedic treatment). This review provides an overview of *Ayurvedic* remedies proposed to counteract the effects of the space environment on astronauts physiology, with particular focus on microgravity and space radiation. It proposes additional evidence driven investigation into diverse medicinal plants to tackle therapeutic obstacles and enhance the utilization of India's traditional medicinal wealth to bolster health and combat severe illnesses.

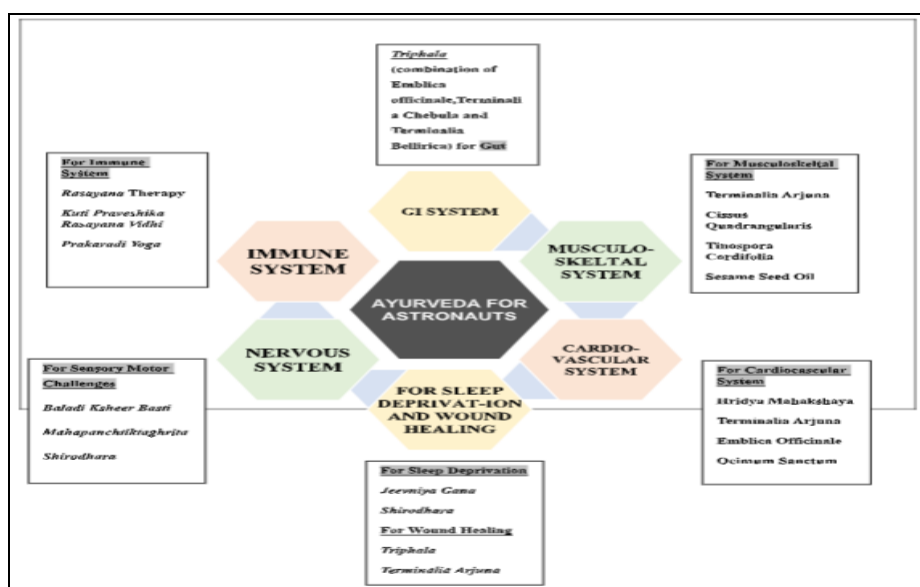


FIG. 1: AYURVEDA FOR SPACE

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