

Review Article

Spaceflight physiology and human resilience: contemporary evidence and Ayurvedic perspectives

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Abstract

With the continued progress of mankind into long-term space voyages, physiological boundaries of the human body emerge as a major concern. Recent experiences by astronauts coming back after being taken into space have pointed out post-flight pathologies such as musculoskeletal weakness, neuro-vestibular dysfunction, cardiovascular changes and slow physiological recovery, which have contributed to the ineffectiveness of existing countermeasures. Contemporary space medicine primarily utilizes reactive, system-specific treatment approaches to manage spaceflight-induced physiological alterations. This narrative review aims to examine a preventive and integrative model associated with matching already existing knowledge on space physiology and classical Ayurvedic principles. A thorough search of the current biomedical literature was performed with the support of databases, including PubMed, Scopus, Google Scholar, and space agency repositories, as well as the analysis of classical Ayurvedic texts and commentaries that would provide the idea of conceptual similarities. The review suggests a synthesizing hypothesis that spaceflight is an extreme *Vata-Prakopaka* condition, which leads to systemic disequilibrium and tissue loss that is the basis of the astronaut pathophysiology spectrum. Ayurvedic interventions such as *Vata-Shamaka* diets, neuro-nourishing *Nasya* treatments and *Ojas*-propping *Rasayana* treatments such as *Ashwagandha* are discussed as possible preventive and resilience-making interventions based on this conceptual model. This integrative approach helps in implementing a paradigm shift of post flight rehabilitation to pre-emptive space medicine tailoring to personalized space medicine as a way of improving human adaptability in future space missions.

Keywords: Space physiology, Space mission, Microgravity, *Vata*, Cosmic radiation

1. Introduction

The growth of human spaceflight to Moon and Mars poses an inherent biological dilemma: the human body adapted to live under the influence of Earth gravity is not well adapted to space conditions. Exposure to the space environment results in multisystem physiological adaptations due to microgravity, space radiation, isolation, and circadian disruption. These adaptations include musculoskeletal deconditioning characterized by muscle atrophy and bone loss, cardiovascular alterations due to cephalad fluid shift and orthostatic intolerance, neurovestibular and neuro-ocular disturbances affecting balance and vision, as well as immune and metabolic dysregulation. Collectively, these changes compromise physiological resilience during long-duration space missions. In spite of the developed countermeasures

against space illnesses in contemporary space medicine, approaches are mostly reductionist and reactive, covering isolated systems instead of overall resilience. These drawbacks in long-term missions underscore the necessity of integrative conceptual frameworks to describe spaceflight-induced dysfunction as a single physiological phenomenon.

2. Methods

The paper adopted a narrative review method to investigate both conceptual and physiological connections between changes induced by spaceflight and classical Ayurvedic concepts. PubMed, Scopus, Google Scholar, and official space-agency repositories (NASA, ESA, ISRO) were searched using the keywords of space physiology and Ayurveda as related to literature (2000-

2025). Search terms included space physiology, microgravity and muscle atrophy, microgravity and bone loss, space radiation and oxidative stress, astronaut health, Ayurveda, Rasayana, and Ashwagandha and muscle strength. Peer-reviewed human studies, reviews as well as authoritative reports were included only. The classical Ayurvedic texts along with commentaries were compared. The results were synthesized qualitatively to come up with an integrative model between space physiology and Ayurvedic theory.

3. Results

3.1 Core Ayurvedic Principles Relevant to Space Physiology

3.1.1 Panchamahabhuta Viewpoint on the Cosmic Space

A balanced interaction of *Panchamahabhuta* elements sustains life on Earth, especially the stabilizing effect of *Prthvi* and the fluid regulation role of *Jala*. Conversely, the space environment is defined by low gravitational stability and fluid cohesion with *Akasha* and *Vayu* having a relative domination. Although the space environment is not inherently *Agni*-dominant, exposure to microgravity, radiation, altered circadian rhythms, and psychological stress may influence physiological and metabolic regulation, suggesting a functional disturbance of *Agni* rather than its predominance. This elemental change conceptually compares to microgravity, redistribution in fluids, and movement-associated stress in spaceflight, and is an Ayurvedic theoretical basis of explaining systemic imbalance and *Vata Prakopa* in astronauts.

3.1.2 Kala (Circadian Rhythm) Dysregulation in Space

Astronauts experience multiple sunrises and sunsets, distorted light exposure, and disrupted sleep-wake rhythm, which causes circadian misalignment.² From an Ayurvedic perspective, disruption of the natural biological rhythm can be conceptually correlated with *Vata* imbalance and functional alteration of *Agni*, which may contribute to fatigue, impaired cognition, and delayed recovery.

3.1.3 Dosha Framework:

Ayurveda describes three regulatory principles- *Vata*, *Pitta*, and *Kapha*. Among them, *Vata Dosha* is most relevant to space physiology, as it is characterized by *Laghu* (lightness), *Ruksha* (Dryness), *Sheeta* (Coldness), *Chala* (Mobility), and *Sukshma* (Subtlety) qualities³ which are conceptually resemble microgravity, environmental instability, and radiation exposure in space. *Pitta* is basically associated with metabolic stress responses, while *Kapha* relates to structural stability and immune function.⁴ During prolonged spaceflight, radiation exposure, oxidative stress, muscle and bone loss, and immune dysregulation may contribute to functional disturbances of *Pitta* and *Kapha*, respectively.

3.1.4 Dhatu Dynamics and Tissue Depletion

The progressive disturbances of the major *Dhatus* provides a useful framework for understanding space-induced degeneration. Disturbances in *Rasa-Rakta* correspond to fluid redistribution and haematological changes; *Mamsa Dhatu* depletion reflects microgravity-induced muscle wasting, while *Meda Dhatu* disturbance may be conceptually correlated with alterations in energy metabolism, lipid utilization, and body composition observed during prolonged spaceflight; and *Asthi-Majja*

imbalance relates to bone loss and neuro-ocular changes observed in astronauts.

3.1.5 Ojas and Resilience Loss:

Ojas, regarded as an essence of all tissue metabolism and systemic resilience,⁵ is particularly challenged during spaceflight. The combined effects of microgravity, radiation, and isolation may contribute to *Ojas* depletion. Microgravity induces muscle and bone loss, fluid redistribution, immune dysregulation, oxidative stress, and metabolic alterations, resulting in progressive *Dhatu Kshaya*. Since *Ojas* is considered the essence of well-nourished *Dhatus*, these systemic changes may conceptually contribute to diminished *Ojas*, leading to reduced physiological resilience and delayed recovery.

3.2 Biophysical Basis of Vata Prakopa in Spaceflight

The space environment is characterized by microgravity, radiation exposure, confinement, and circadian disruption, all of which alter normal physiological homeostasis. From an Ayurvedic perspective, these environmental stressors can be interpreted through the predominance of specific *Vata Gunas*.

Microgravity removes the constant gravitational load on the body, producing a state of *Laghu* (lightness) due to weightlessness and reduced mechanical loading. The cephalad redistribution of body fluids reflects excessive *Chala* (mobility), as normal fluid dynamics become altered in the absence of gravity. Progressive muscle wasting and bone demineralization resemble the predominance of *Ruksha* (dryness) and *Laghu*, representing tissue depletion (*Dhatu Kshaya*). Together, these *Guna* alterations provide a conceptual basis for interpreting spaceflight as an extreme *Vata Prakopa* state that underlies the multisystem physiological adaptations observed during prolonged missions.

3.3 Systematic Correlation: Space Physiology According to Ayurvedic view

3.3.1 Musculoskeletal System: Degradation induced by Vata in a Comprehensive Analysis.

Loss of gravitational resistance and decreased proprioceptive feedback from muscle and joints under microgravity creates a condition of mechanical unloading. This leads to neuromuscular deconditioning, changes in motor unit recruitment, and increased muscle protein breakdown, which eventually cause spaceflight-related sarcopenia and bone loss.⁶ According to *Ayurveda*, absence of load and grounding is an indication of predominance of *Laghu* (light) *Ruksha* (Dryness) and *Chala* (portable) *Gunas* that directly aggravates *Vata* at the *Mamsa* and *Asthi Dhatu* levels.⁷ This *Vata Prakopa* affects tissue nutrition, stability and repair leading to degeneration, and musculoskeletal fragility in the event of spaceflight. These mechanical modifications give rise to the musculoskeletal changes in the system specific to spaceflight, which are described below.

Bone Metabolism and Structural Changes:

Bone remodelling Dynamics: Microgravity induces rapid uncoupling of bone remodelling processes. Osteoclast activity increases within the first month while osteoblast activity is suppressed resulting in a resorption-dominant state.⁸

Mineral Homeostasis: Accelerated skeletal calcium release leads to persistent hypercalciuria (200- 300

mg/day), increasing the risk of renal stone formation.⁹

Asthi Dhatu Kshaya (Bone Tissue Depletion):

Vata Dominance Mechanism: Microgravity may be conceptually interpreted as a state characterized by the predominance of *Laghu* (light) and *Chala* (mobile) *Gunas* of *Vata*, which contrasts with the *Guru* (heavy) and *Sthira* (stable) *Gunas* required for maintaining bone mass and structural integrity.¹⁰

Pattern of Srotodushti, The *Asthivaha Srotas* exhibits *Vataja* type obstruction, which is shown by:

Atipravritti: The symptom is expressed as excessive calcium release and bone resorption.

Siragranthi: Impaired nourishment of osteocytes due to obstructed microcirculation.

3.3.2 Muscle Architecture and Function:

Protein Turn over Dynamics: Myofibrillar protein synthesis rates decreases whereas Ubiquitin-proteasome pathway activity increases, which is an indication of increased protein degradation.¹¹

Neuromuscular Changes: Motor unit recruitment patterns are disturbed with reduction in maximal voluntary contraction force and decreased muscle endurance.¹²

Muscle Tissue Depletion (Mamsa Dhatu Kshaya):

Manifestation of Gunas Imbalance:

Ruksha (dry) Guna: May be associated with muscle protein degradation and tissue catabolism contributing to *Mamsa Dhatu Kshaya*.¹³

Chala (mobile) Guna: May conceptually correspond to altered neuromuscular coordination and postural instability resulting from microgravity-induced sensorimotor adaptation.¹⁴

Laghu (light) Guna: Contributes to progressive reduction in skeletal muscle mass and muscle strength due to unloading under microgravity.¹⁵

3.3.3 Cardiovascular System: A comprehensive derangement of Vyana Vayu.

Microgravity results in central fluid shifts, decreased plasma volume, and autonomic dysregulation leading to orthostatic intolerance and cardiovascular deconditioning.¹⁶ The circulation is controlled by *Vyana Vayu* in Ayurvedic terms, which distributes blood and other nutrients to the body.¹⁷ The loss of gravitational gradients and sensory signals in space interferes with normal functioning of *Vyana Vayu*, which coordinates circulation and tissue perfusion. This *Vata*-based disequilibrium is the cause for the cardiovascular deconditioning in spaceflight.

Hemodynamic and Fluid Shift Dynamics:

Within 2-6 hours of microgravity condition, 1.5-2 liters of fluid are redistributed, cephalad of lower extremities raising central blood volume and cardiac output.¹⁸

Response of atrial Stretch: Increase in atrial natriuretic peptide (ANP) secretion. In 24 hours, evoking diuresis and natriuresis which decreases plasma volume in 2-3 days.¹⁹

Baroreceptor Remodelling: Carotid and aortic baroreceptor remodelling occurs within 3-7 days.²⁰

Cardiac changes (anatomical and physiological)

Cardiac Morphology: Ventricular mass reduces in a period of 6 months and Thickening of the myocardial walls diminishes mainly in the interventricular septum.²¹

Diastolic Function: Early Diastolic filling velocity (E-wave) reduces and there is an increase in atrial contrac-

tion velocity (A-wave) which points to poor ventricular relaxation.²²

Post-Flight Orthostatic Intolerance:

Hemodynamic Collapse: 60-80% of astronauts develop presyncope during stand tests that are characterized by drop in systolic blood pressures in addition to a rise in heart rates that is not adequate to sustain cerebral perfusion.²³

Catecholamine Response: The plasma norepinephrine levels decrease in orthostatic stress, which demonstrates that the sympathetic nervous system is dysfunctional.²⁴

Ayurvedic correlation in detail by using Guna Theory

Vyana Vayu Dysfunction: The cardiovascular adaptations observed in spaceflight primarily reflect a disturbance of *Vyana Vayu*, which normally governs the distribution of *Rasa* and *Rakta* throughout the body via the heart and blood vessels.¹⁷

The *Gunas* involved are *Chala* (mobile) *Guna* promotes multidirectional and uncontrolled fluid movement, leading to hemodynamic instability.¹⁴ *Ruksha* (dry) *Guna* leads to plasma volume depletion and impaired endothelial function.¹³

Rasa and Rakta Dhatu Pathology:

Rasa Dhatu Kshaya: Plasma volume depletion represents classical *Rasa Dhatu Kshaya*, leading to impaired nourishment of all tissues.²⁵

Rakta Dhatu Vaishmya: Alterations in the composition and circulation of blood reflect qualitative derangement of *Rakta Dhatu*.

Srotodushti Pattern: A *Vataja* type obstruction is manifested by the *Rasavaha* and *Raktavaha Srotas* with *Vimarga Gamana* (Abnormal distribution of fluids) and *Sanga* (May conceptually correspond to increased blood viscosity, impaired microvascular circulation, and altered tissue perfusion) during spaceflight.

Changes in Hridaya (Heart):

Structural Impact: Microgravity-induced cardiac atrophy may be conceptually correlated with the predominance of *Vata Gunas* (*Laghu* and *Chala*), opposing the *Guru* and *Sthira* qualities essential for maintaining myocardial mass and structural stability.

Functional Effect: Impaired diastolic function and reduced contractility may be conceptually associated with disturbed *Sadhaka Pitta*, resulting in reduced cardiovascular adaptability during prolonged spaceflight.

3.3.4 Neuro-Ocular System: Spaceflight-Associated Neuro-Ocular Syndrome (SANS) as Prana Vayu and Alochaka Pitta Pathology.

SANS is characterized by optic disc edema, flattening of the globe, folds in the choroid, and visual impairment due to the long missions. These results are associated with cephalad shifts of fluid, and modified intracranial and venous drainage in microgravity.²⁶ According to Ayurveda, *Prana Vayu* governs neural regulation, *Alochaka Pitta* is responsible for visual perception, while *Tarpaka Kapha* nourishes and maintains the functional integrity of the brain and sensory organs.²⁷ The disturbance of cranial fluid dynamics in microgravity may conceptually disrupt the coordinated functions of *Prana Vayu*, *Alochaka Pitta*, and *Tarpaka Kapha*, leading to impaired neuro-ocular homeostasis and visual dysfunction.

Intracranial Pressure and Cerebrospinal Fluid Dynamics

CSF Redistribution: Microgravity results increase in

intracranial pressure (ICP) of which 40-60% of astronauts have apparent optic disc edema.²⁸

Lymphatic Drainage: The functioning of the glymphatic system (the brain's waste-clearance pathway responsible for removing metabolic waste through cerebrospinal fluid circulation) is reduced and diminished clearance of neural metabolite waste products.²⁹

Ocular Structural Changes:

Choroidal Pathology: Choroidal thickness increases, and about 40% of long duration crew members shows choroidal folds in optical coherence tomography³⁰.

Neurological changes: 20-30% of the astronauts exhibit optic disk edema and retinal nerve fibre layer gets thickened³¹.

Visual Functional impairment:

Visual Acuity: Reduction in near-vision performance is observed despite best-corrected vision³².

Dark Adaptation: Increase in the dark adaptation time of the rods meaning a deficit of photoreceptor functioning.³³

Ayurvedic correlation in detail by using Guna theory.

Prana Vayu Disturbance in Shiras:

Obstruction in Primary Pathway: Microgravity-induced cephalad fluid shift may conceptually disturb the normal functions of *Prana Vayu* in *Shiras*, leading to altered neurophysiological regulation and impaired cranial fluid homeostasis. The *Gunas* imbalanced are *Drava* (liquid) *Guna* overfills of CSF and vascular fluids in the head. *Sandra* (dense) *Guna* imparts tissue congestion and dense tissue in optic structures³⁴. *Chala* (mobile) *Guna* produces fluid movement which is unstable and has an influence on the homeostasis in the eyes¹⁴.

Alochaka Pitta Pathology:

Functional Impairment: *Alochaka Pitta* may be functionally disturbed during spaceflight, leading to impaired visual processing and compromised ocular tissue integrity.

Structural Manifestations: Disturbed *Alochaka Pitta* may conceptually correlate with vascular changes, while *Tarpaka Kapha* disturbance may be associated with altered fluid homeostasis and tissue nourishment, contributing to optic disc edema and choroidal thickening.

Srotodushti Patterns - Majjavaha Srotas : Microgravity-induced alterations in cerebrospinal fluid dynamics and neural function may be conceptually correlated with *Vataja Srotodushti*, affecting the normal functions of *Majjavaha Srotas*.

Raktavaha Srotas: Radiation-induced vascular changes, venous congestion, and altered ocular perfusion may be conceptually associated with *Pittaja Srotodushti* involving the *Raktavaha Srotas*.

Pranavaha Srotas: The combined effects of altered cerebral perfusion, cephalad fluid shift, and impaired neurophysiological regulation may be conceptually interpreted as a *Vata-Pitta* disturbance affecting the *Pranavaha Srotas*.

3.3.5 Immune System: Extensive Ojas Depletion When Stressed by Space.

Spaceflight environments have a devastating effect on immune regulation by microgravity, radiation, circadian disruption and psychological stress. These contribute to the cellular immune suppression, cytokine imbalance and reactivation of dormant viruses.³⁵ In Ayurveda, immune strength (*Vyadhi-Kshamatva*) is closely related to *Ojas*.³⁶ Prolonged exposure to microgravity, space radiation, psychological stress, circadian disruption, and systemic *Dhatu Kshaya* may conceptually compromise *Ojas*, thereby reducing physiological resilience and immune competence. Hence, spaceflight may be interpreted as a classical *Ojohara* condition, predisposing astronauts to systemic dysfunction and increased disease susceptibility.

Cellular Immune Dysfunction:

Leukocyte Redistribution: The circulating T-lymphocytes reduced within first 48 hours and sequestration occurs selectively in secondary lymphoid organs³⁷.

Functional Impairment: Decrease in T-cell receptor signalling activation potential, and decrease in cytotoxic T-cell activity³⁸.

Humoral and Cytokine Alterations:

Dysregulation of Cytokines: Pro-inflammatory cytokines (IL-6, TNF- α , IL-1 β) increase 2-4-fold, whereas anti-inflammatory cytokines (IL-10, IL-4) decreases³⁹.

Interferon Response: Production of type I interferon was inhibited, which diminished the antiviral defense⁴⁰.

Ayurvedic correlation in detail by using Guna Theory.

Mechanism Ojas Depletion:

Sustained exposure to microgravity, radiation, isolation, and circadian disruption constitutes a classical *Ojohara* state, leading primarily to depletion of *Apara Ojas*, while prolonged and severe physiological stress may conceptually threaten the preservation of *Para Ojas*.

Guna Imbalance Manifestation:

Sheeta (cold) *Guna* has immunosuppressive effect, slowing down the activation and growth of the immune cells⁴¹. *Ruksha* (dry) *Guna*: weakens mucosal barriers and cellular communication⁴².

Bala and Vyadhi-kshamatva Impairment:

Sahaja Bala Loss: Natural immune capacity becomes weak and is manifested by the loss of neutrophil and natural killer cell activity.

Kalaja Bala Disruption: There is circadian disruption of age and rhythm-dependent immune functions.

Yuktikrita Bala Exhaustion: Despite nutritional and exercise countermeasures, prolonged spaceflight may impair acquired physiological resilience, conceptually corresponding to reduced *Yuktikrita Bala*.

3.4 Proposed integrative countermeasure frame work

Based on the established physiological correlations, an evidence-based integrative Ayurvedic model is proposed to complement existing space medicine countermeasures. The framework integrates *Vata Shamaka Rasayana* therapy with contemporary mission-specific interventions to enhance physiological resilience, minimize spaceflight-induced deconditioning, and support astronaut health across different mission phases. The proposed interventions, their intended applications, and supporting evidence are summarized in below Table 1.

The proposed interventions are conceptual and intended as adjuncts to existing space medicine counter-

Table 01. Proposed Ayurvedic interventions for astronaut healthcare

Ayurvedic intervention	Purpose in spaceflight	Supporting evidence
<i>Ashwagandha (Withania somnifera)</i>	Maintains muscle health, stress adaptation	Reduces cortisol, enhances antioxidant defence, and improves muscle strength, ⁴³ suggesting potential against stress- and microgravity-associated physiological deconditioning.
<i>Guduchi (Tinospora cordifolia)</i>	Immunomodulation	Immunomodulatory and antioxidant; regulates inflammatory cytokines, ⁴⁴ potentially supporting spaceflight-associated immune function.
<i>Bala (Sida cordifolia)</i>	Neuromuscular support	Traditionally used to support neuromuscular strength and function. ⁴⁵
<i>Abhyanga with Maha Narayan Taila</i>	Improves tissue perfusion; adjunct to resistance exercise	May complement resistance training by improving tissue perfusion and
<i>Brahmi (Bacopa monnieri)</i>	Sleep quality, cognition, neuroprotection	Neuroprotective, antioxidant, and cognition-enhancing effects. ⁴⁸
<i>Amalaki (Emblica officinalis)</i>	Antioxidant and radioprotective support	Rich in vitamin C and polyphenols; ⁴⁹ may reduce oxidative stress and support radioprotection.
<i>Arjuna (Terminalia arjuna)</i>	Cardiovascular support	Proposed as an adjunct to LBNP sessions to support cardiovascular adaptation. ⁵⁰
<i>Triphala</i> eye wash	Neuro-ocular support	Potential adjunct for ocular health; ⁵¹ requires validation for spaceflight.

measures. Their efficacy, dosage, safety, and feasibility in astronauts require validation through future preclinical and clinical studies.

Beyond pharmacological interventions, the proposed integrative model also emphasizes circadian and metabolic optimization as essential components of astronaut healthcare. The key component is Circadian and Metabolic Optimization with a structured *Kala-Charya* regimen that synchronizes the timings of meals, exercise and sleep with the cosmic cycles and an *Agni* Restoration Program based on warm, moist, easily digestible foods with digestive spices to correct the *Vishmaggni*.

Implementation is proposed across all mission phases-

Pre-flight: Preparations that include individual *Prakriti* assessment and conditioning

In-flight: Daily integrative routines with real-time biomarker monitoring

Post-flight: Gradual re-adaptation with prolonged *Rasayana* therapy.

Expected outcome include decrease in bone density loss, improved orthostatic tolerance, decrease in SANS incidence, and preservation of muscle mass, better immune system, sleep quality and psychological resiliency. This represents a paradigm shift from reactive symptom management to proactive systems-based support and treats the underlying *Ojo Kshaya* and *Vata Prakopa* that causes space adaptation syndrome and establishing a comprehensive basis of human health in the extreme space environment.

4. Discussion, challenges, and research propositions

The proposed integrative framework represents a paradigm shift in the field of space medicine, moving

from a compartmentalized, disease-centric model to a holistic resilience-based approach. This review offers a comprehensive explanation of the multi-systemic deconditioning experienced by astronauts by interpreting spaceflight pathophysiology through the Ayurvedic principles of *Vata Prakopa*, *Dhatu*, and *Ojas Dusti*. The advantage of this solution is that it will target the underlying causes and not the single symptoms, providing the possibility of long-term health maintenance during more extended missions. Nevertheless, a number of major challenges should be recognized and overcome by conducting intense scientific research.

The major challenges would be to fit the traditional Ayurvedic practices under the space environment. Most of the basic interventions, including *Abhyanga* (oil massage), *Swedana* (therapeutic sweating), and fresh herbal formulation preparation need significant modification for microgravity conditions. Similarly, classical interventions such as *Nasya* and *Vata-Shamaka* dietary regimens present operational challenges in space. Free liquid formulations may disperse in microgravity, increasing the risk of aspiration, while fresh whole-food preparations have limited feasibility during long-duration missions. Therefore, future space-compatible adaptations, including metered-dose intranasal sprays, aerosolized formulations, standardized gel-based preparations, or encapsulated herbal extracts, should be explored while maintaining the conceptual principles of Ayurvedic therapeutics.

There is the risk of using oil-based therapies which can lead to the contamination of spacecraft air filters, and the fact that the metabolic needs of some procedures cannot be accommodated with other mission requirements. Moreover, the individualism of the Ayurvedic medicine is based on *Prakriti* assessment will need to be countered by the standardized procedures

required in the operations of space missions. Pre-flight *Prakṛti* assessment may also help identify individual susceptibility to spaceflight-induced physiological deconditioning. From an Ayurvedic perspective, individuals with *Vata Pradhana Prakṛti* may be more vulnerable to microgravity-induced musculoskeletal loss, neurovestibular disturbances, and psychological stress because of the inherent predominance of *Laghu*, *Ruksha*, and *Chala Guṇas*. In contrast, *Kapha Pradhana* individuals may demonstrate relatively greater structural stability and tissue preservation due to the predominance of *Guru* and *Sthira Guṇas*, although they may be more prone to metabolic adaptation during prolonged missions. *Pitta Pradhana* individuals may be relatively more susceptible to oxidative and radiation-induced stress because of their predominance of *Agni* and metabolic activity. Such individualized risk stratification could facilitate personalized preventive strategies before space missions.

Scientific validation is another significant challenge; although there are some early signs pointing to the effectiveness of most of the suggested interventions, space-specific research is required to establish safety profiles, optimum dosing, pharmacokinetics in microgravity, and potential interactions with conventional medications. Furthermore, before integration into astronaut healthcare, Ayurvedic interventions must undergo rigorous safety and toxicological evaluation, quality standardization, and regulatory assessment in accordance with established space medicine and pharmaceutical guidelines. Standardized formulations with consistent quality, stability, and efficacy should be developed to ensure safe consumption during long-duration space missions.

The following are some directions that should be given priority in future research - First, laboratory research (isolation chambers) should be used to evaluate the effectiveness of core interventions like *Rasayana* therapy and *Vata*-pacifying diets in microgravity conditions i.e space relevant physiological parameters. Second, technological innovation is needed to develop space-compatible delivery systems for Ayurvedic interventions such as water-based alternatives to oil therapies, herbal preparations with a stable long shelf-life, and miniaturised diagnostic tools for assessing *Prakṛiti* and *Agni*. As spaceflight is associated with altered metabolism, gastrointestinal function, and circadian rhythm, future studies should investigate their potential impact on *Agni* and validate objective biomarkers for its assessment. Third, longitudinal researches should be conducted on the interactions between Ayurvedic and modern countermeasures, with special attention to their potential in terms of minimizing the exercise time needs and retaining physiological resilience. Finally, the cultural and implementation issue of how traditional medicine can be incorporated into severely technological space settings must be addressed, including astronaut training, acceptability, and standardisation of protocols, needs to be studied.

The Implications of this Ayurvedic integrative approach extend beyond space medicine. Bridging classical knowledge with the modern science would mean a new benchmark in the field of medical practice in extreme conditions on Earth and even, perhaps, educate preventive care practices among terrestrial populations with the same issues. When these two medical paradigms are bridged, we not only open the possibilities of improving human resilience in space but also open the possibility of improving our basic understanding of

human physiology and adaptations. This process of achieving sustainable interplanetary life can easily rely on such integrative methods that respect both classical and scientific knowledge.

5. Conclusion:

This comprehensive review has established a pioneering theoretical framework bridge between the ancient science of Ayurveda and the contemporary issues of human spaceflight. By systematically explaining how the pathophysiological changes induced by Spaceflight-across musculoskeletal, cardiovascular, neuro-ocular, immune, and Metabolic systems- align with the Ayurvedic theory of *Vata Prakopa*, *Dhatu*, and *Ojas Dusti*. we have given a new integrated structure of being familiar with space adaptation syndrome. The proposed integrative model advances beyond the reactive paradigm of conventional space medicine by adopting a proactive, whole-person approach aimed at strengthening intrinsic physiological resilience rather than fixing symptoms separately.

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