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"VYAYAMA (EXERCISE) PHYSIOLOGY IN AYURVEDA: EXPLORING BIOLOGICAL INDICATORS OF OPTIMAL EXERCISE LIMITS (*ARDHA SHAKTI*) TO PREVENT OVERTRAINING SYNDROME AND EXERCISE-INDUCED OXIDATIVE STRESS."

Dr. Sunil Kumar[1*], Dr. Bajrang Ramawat[2], Dr. Radhika Mahajan[3], Dr. Sarvesh Kumar Agrawal[4]

[1*]PG Scholar, P.G. Department of Swasthavritta & Yoga, NIA, Jaipur, Rajasthan.
[2]Assistant Professor, Department of Swasthavritta & Yoga, NAMC, Agra.
[3]P.G. Scholar, P.G. Department of Swasthavritta & Yoga, NIA, Jaipur, Rajasthan.
[4]Associate Professor, P.G. Department of Swasthavritta & Yoga, NIA, Jaipur

***Corresponding Author:** Dr. Sunil Kumar
*PG Scholar, P.G. Department of Swasthavritta & Yoga, NIA, Jaipur, Rajasthan.

ABSTRACT

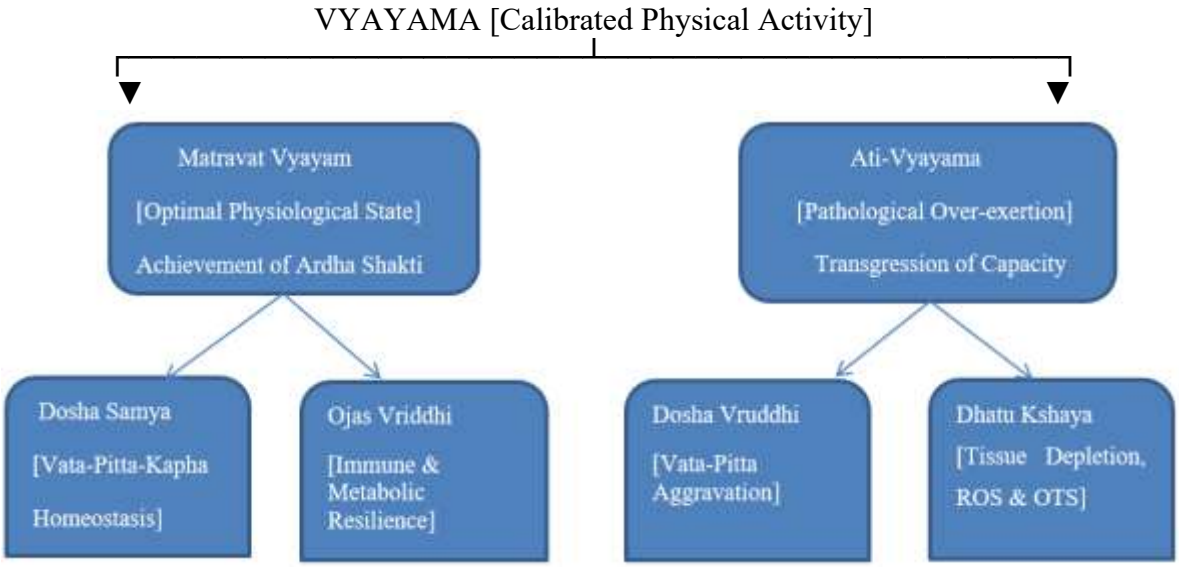
Modern sports science increasingly identifies overtraining syndrome (OTS) and exercise-induced oxidative stress as premier threats to long-term athletic development and general physiological homeostasis. While contemporary exercise immunology and biochemistry rely on complex biomarkers to map the threshold between performance enhancement and systemic exhaustion, ancient Ayurvedic physiology established a highly precise, subjective, and clinically measurable framework known as ***Ardha Shakti*** (half of one's total physical capacity).

This article explores *Vyayama* (physical exercise) physiology within classical Ayurvedic treatises, establishing the biological markers of *Ardha Shakti* as predictive indicators that mimic contemporary ventilatory, cardiovascular, and metabolic thresholds. By integrating classical concepts of *Dosha* dynamics (*Vata-Pitta-Kapha*), *Dhatu Agni* (cellular metabolism), and *Ojas* (systemic immunity) with contemporary pathophysiological pathways of Reactive Oxygen Species (ROS) and neuroendocrine dys-regulation, this treatise demonstrates how the systematic application of Ayurvedic limits safely bypasses the tipping point into overtraining.

Key words: - *Vyayama, Ardha Shakti*, Oxidative Stress

1. INTRODUCTION:

The Concept of *Vyayama* in Ayurveda:-In the Ayurveda system, *Vyayama* is categorized as an indispensable element of *Dinacharya* (daily preventive and promotive lifestyle regimens) [1]. Acharya Charaka defines *Vyayama* as any physical activity that produces bodily stability (*Sthairya*) and structural strength (*Bala*) when performed in a calibrated manner (*Matravat*) [1]. Acharya Sushruta expands this definition by adding that an activity causing bodily weariness or purposeful tiredness (*Ayasa*) constitutes *Vyayama* [2].



Unlike contemporary fitness paradigms that often champion an absolute, exhausting output ("no pain, no gain"), Ayurvedic physiology treats exercise as a phenomenon that possesses a precise therapeutic window [16]. When prescribed and practiced within individual physiological tolerances, *Vyayama* provides deep lightness of the skeletal frame (*Gatra Laghava*), striking enhancement of the digestive and metabolic fire (*Agni Upachaya*), and stabilization of stagnant adipose tissue (*Medas*) [4, 5].

However, if physical exertion transcends the individual threshold—transforming into *Ati-Vyayama* (excessive exercise)—it induces immediate structural decay (*Dhatu Kshaya*) and chaotic vitiation of the biological humors, leading to multi-system failure resembling modern clinical Overtraining Syndrome [6, 19].

2. THEORETICAL FRAMEWORK OF *ARDHA SHAKTI* (THE HALF-CAPACITY CEILING)

The cornerstone of Ayurvedic sports safety is the doctrine of **"Ardha Shakti"** or **"Balardha"** [2, 3]. Classical texts mandate that healthy individuals should restrict their daily physical exercise to exactly half of their total individual energy capacity [14].

This mathematical division of physical exertion ensures that the body harnesses the anabolic benefits of physical conditioning without slipping into a catabolic state [7, 8]. The determination of *Ardha Shakti* is not arbitrary; it relies on real-time feedback from the cardiorespiratory and integumentary systems [12].

According to the foundational texts of *Sushruta Samhita* the exact onset of *Ardha Shakti* is heralded by specific clinical expressions [2].

- **Hrid-Avasthit Prana Vayu Movement (The Cardio-Pulmonary Shift):** The precise moment when the air residing in the deeper chest cavity (*Prana Vayu*) ascends through the respiratory tract and escapes through the oral cavity, manifesting as deep, accelerated diaphragmatic breathing [2].
- **Sweda Pravritti (Incipient Diaphoresis):** The presentation of beads of sweat specifically localized across the forehead (*Lalata*), nose (*Nasa*), axillae (*Kaksha*), and main articulatory joints (*Sandhi*) [2].
- **Mukha Shosha (Xerostomia):** The development of noticeable dryness in the oral cavity and throat, signifying shifts in fluid dynamics and sympathetic tone [2].
- **Gatra Laghava (Sensation of Lightness):** A post-exercise neurological feedback of physical buoyancy and psychological clarity, indicating that metabolic waste products (*Klama*) have not yet saturated the cellular matrices [9, 15].

3. MODERN PHYSIOLOGICAL CORRELATES OF *ARDHA SHAKTI*

The Ayurvedic bio-indicators of *Ardha Shakti* present a remarkable overlap with modern exercise physiology parameters, charting the transition between aerobic metabolism and anaerobic thresholds [4, 12].

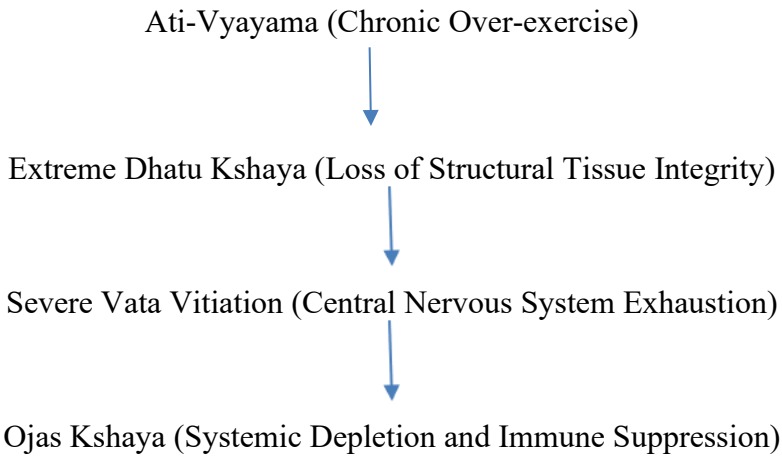
Ayurvedic Bio-Indicator	Sanskrit Term	Modern Physiological Correlate	Functional Mechanism
Oral Breathing Acceleration	*Hrid-Avasthit Prana Vayu* Movement [2]	**Ventilatory Threshold 1 & 2 (VT1/VT2)**	Transition from aerobic to anaerobic metabolism; accumulation of CO_2 drives heavy diaphragmatic respiration.
Localized Sweat Onset	*Sweda Pravritti* [2]	**Thermoregulatory / Sudorific Point**	Eccrine gland activation driven by core temperature changes and sympathetic nervous system discharge.
Oral Cavity Dryness	*Mukha Shosha* [2]	**Sympathoadrenal Activation Threshold**	Parasympathetic withdrawal coupled with profound salivary gland vasoconstriction via alpha-adrenergic receptors.
Sensation of Lightness	*Gatra Laghava* [9]	**Lactate Clearance Equilibrium**	Muscle glycogen utilization occurs within limits where pyruvate oxidation is matched, avoiding lactic acidosis.

When an athlete matches the *Hrid-Avasthit Prana Vayu* movement marker, they have achieved what modern science recognizes as the **Ventilatory Threshold (VT1)** or the **Lactate Threshold (LT)** [12]. At this point, blood lactate concentrations begin to rise systematically above baseline levels (~2 mmol/L) [20].

The involuntary shift to oral breathing serves to clear excess carbon dioxide produced by the buffering of lactic acid. By advising the practitioner to halt major exertion at this exact junction, Ayurveda ensures the metabolic pathway remains heavily sustained by lipid oxidation, avoiding the deep glycogen depletion, severe acidosis, and autonomic exhaustion linked with extended high-intensity training [4, 17].

4. OVERTRAINING SYNDROME (OTS) THROUGH THE PRISM OF *ATI-VYAYAMA*

Modern sports medicine describes Overtraining Syndrome (OTS) as a maladaptive response to excessive exercise combined with inadequate recovery [19]. This syndrome leads to prolonged performance decrements, neuroendocrine disruption, mood alterations, and systemic immune suppression [19]. Ayurvedic pathology provides an identical mirror image of this state under the classification of ***Ati-Vyayama Roga*** or ***Dhatu Kshaya*** resulting from *Shrama* (exhaustion) [1, 6].



When the *Ardha Shakti* ceiling is chronically violated, a pathological chain reaction alters the body's internal homeostasis (*Dhatu Vaishamya*) [17, 18]:

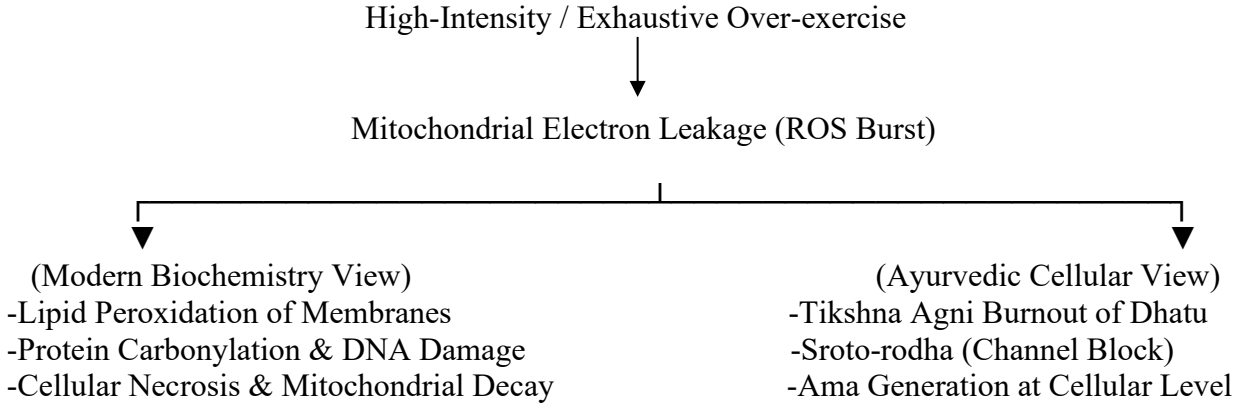
- **Vata Dosha Aggravation:** Excess movement directly escalates *Ruksha* (dryness), *Laghu* (lightness), and *Chala* (mobility) attributes of *Vata* [1]. The *Prana*, *Udana*, and *Vyana* sub-types of *Vata* control neurological feedback, cardiovascular rhythm, and motor output [15]. Their chronic destabilization mirrors the central nervous system fatigue, insomnia, bradycardia/tachycardia, and emotional instability seen in sympathetic/parasympathetic OTS [19].
- **Pitta Dosha Hyper-reactivity:** Severe exertion generates deep internal thermal energy (*Ushma*), provoking *Pitta Dosha* [7]. This creates inflammatory currents within the plasma (*Rasa*) and muscular (*Mamsa*) tissue channels, aligning closely with systemic low-grade muscle inflammation and elevations in pro-inflammatory cytokines (IL-6, TNF-α) [10].
- **Kapha Dosha Depletion:** *Kapha*, which gives structural stability, lubrication, and anabolic protection, is systematically depleted, leading to the erosion of cellular resilience [8].

The cascading failure of overtraining fundamentally targets the structural tissues (*Dhatus*). Under the duress of *Ati-Vyayama*, *Rasa Dhatu* (plasma and lymph) dries up rapidly, inducing dehydration and poor nutrient transport [1]. Following the sequential chain of tissue nourishment (*Dhatu Poshana Krama*), the degradation moves to *Mamsa Dhatu* (skeletal muscle) and *Medas Dhatu* (adipose tissue), manifesting as chronic muscle wasting, structural micro-tears, and structural weight loss [6, 17].

The final casualty of this catabolic cascade is ***Ojas*** (the ultimate vital essence of all biological tissues, responsible for immunity, psychological resilience, and cellular integrity) [1]. A drop in *Ojas* (*Ojo-Kshaya*) matches perfectly with the clinically proven profile of an overtrained athlete: high vulnerability to upper respiratory tract infections (URTIs), suppressed immunoglobulin levels (sIgA), persistent lethargy, and an inability to adapt to standard physical stress [16, 19].

5. EXERCISE-INDUCED OXIDATIVE STRESS AND AYURVEDIC CELLULAR ENERGETICS

One of the key physiological dangers of exceeding *Ardha Shakti* is **Exercise-Induced Oxidative Stress** [10, 12]. While moderate, structured physical activity upregulates endogenous antioxidant defenses, exhaustive, uncalibrated training overpowers these systems, leading to an overproduction of Reactive Oxygen Species (ROS), causing severe lipid peroxidation, protein carbonylation, and DNA damage [10, 11].



From an Ayurvedic viewpoint, oxidative stress represents a functional crisis of **Dhatu Agni** (tissue-specific metabolic fires) and the creation of **Ama** (toxic, highly reactive metabolic byproducts) at the cellular level [15, 17]. When exercise is kept within *Ardha Shakti*, *Agni* is optimally stimulated (*Samagni*), ensuring complete combustion of nutrients and orderly tissue synthesis [4].

However, when an individual pushes into extreme anaerobic zones, the tissue-specific metabolic fires are subjected to an unmanageable demand [5]. This creates a state analogous to *Tikshna Agni*

(hyper-reactive, destructive combustion) followed by an immediate crash into *Mandagni* (metabolic exhaustion) [9]. The incomplete synthesis of *Dhatu* matrices generates a subtle form of cellular *Ama* [15]. This *Ama* acts identically to free radicals; it disrupts cellular membrane permeability, clogs the microscopic transport channels (*Srotas*), and blocks the delivery of vital oxygen and nutrients to tissues [15, 17].

The free radical storm triggered by *Ati-Vyayama* causes severe structural damage to two key tissue complexes [6, 20]:

1. **Mamsa Dhatu:** Severe ROS production targets the lipid bilayers of the sarcoplasmic reticulum [20]. This leads to impaired calcium homeostasis, persistent muscular pain (*Shula*), loss of contractility, and delayed onset muscle soreness (DOMS) [11, 20].
2. **Shukra Dhatu:** In Ayurvedic anatomy, *Shukra Dhatu* (reproductive and deep regenerative tissue) sits at the peak of the tissue evolution chain [1]. Because it requires maximal anabolic energy and structural protection, it is highly sensitive to oxidative stress [20]. Excessive physical training shunts biological resources away from reproduction to fuel basic survival, a phenomenon known modernly as Relative Energy Deficiency in Sport (RED-S), presenting clinically as suppressed testosterone-to-cortisol ratios and diminished spermatogenesis [19].

6. PERSONALIZING EXERCISE ARCHITECTURE: THE VARIABLES OF *BALA*, *PRAKRUTI*, AND *KALA*

Ayurveda explicitly denies the existence of a universal, standardized exercise prescription [13]. The exact point at which an individual reaches *Ardha Shakti Vyayama* fluctuates daily based on an intricate array of personal and environmental variables [14]:
Ardha Shakti Vyayama depends upon various factors like Prakruti, Vaya, Bala, Kala, Desha, Ahara etc.

Prakruti (Individual Constitution)

An individual's unique genetic and phenotypic constitution alters their native exercise capacity (*Vyayama Shakti*) [13, 14]:

- **Kapha-Dominant Prakruti*:*** Individuals with a *Kapha* constitution possess inherently strong, well-lubricated joints, dense skeletal muscle architecture, and superior endurance capabilities (*Uttama Bala*) [13]. They require high-volume, steady-state, dynamic exercise to clear metabolic congestion and maintain physiological balance [8]. Their transition to *Ardha Shakti Vyayama* is delayed, allowing them to tolerate longer training durations [13].
- **Pitta-Dominant Prakruti:** Individuals with a *Pitta* constitution possess moderate physical strength (*Madhyama Bala*) but generate substantial internal metabolic heat [13]. High-intensity training in hot environments quickly pushes them into hyperthermia, accelerating oxidative stress and *Pitta* vitiation [10]. They require structured, non-exhaustive training with a focus on cooling environments and mindfulness practices [5].
- **Vata-Dominant Prakruti:** Individuals with a *Vata* constitution possess a fragile skeletal frame, minimal adipose reserve, and low baseline stamina (*Alpa Bala*) [13]. Their nervous systems are naturally prone to hyper-activation [15]. Pushing a *Vata* individual to standard modern fitness capacities accelerates *Dhatu Kshaya* and central fatigue within minutes [6]. Their *Ardha Shakti Vyayama* threshold is brief; they respond best to grounding, low-impact, highly structured movements like slow-paced yoga, swimming, and brief resistance training [7].

Kala (Seasonal Variations) Ayurvedic chronobiology notes that environmental seasons alter human physiological strength (*Sharira Bala*) [3].

- **High Strength Seasons (Hemanta, Shishira, Vasanta):** During late autumn, winter, and early spring, the environmental *Soma* (cooling, nourishing energy) is dominant [3]. The human body retains internal heat, and *Bala* is naturally elevated [13]. During these seasons, an individual can

safely pursue a robust implementation of the *Ardha Shakti Vyayama* rule, engaging in heavier resistance work and higher cardiorespiratory loads [3].

- **Low Strength Seasons (Grishma, Varsha, Sharad):** During summer, the monsoon season, and early autumn, environmental dehydration and humidity drain human physical capacity [3]. The baseline *Bala* drops to its lowest tier [13]. During these intervals, the *Ardha Shakti Vyayama* ceiling is reached rapidly [14]. Continuing with intense winter training loads during summer causes rapid oxidative stress, electrolyte imbalance, and clinical exhaustion [10, 18].

Vaya (Age)

- **Balyavastha (Childhood / < 16 years):** Physical structures and tissues (*Dhatus*) are still developing. Strenuous exercise is contraindicated; limits are minimal.
- **Yuva & Madhya Vaya (Adult / 16–70 years):** The prime period for regular physical cultivation. Tissues are stable, allowing a significantly higher baseline for *Ardha Shakti Vyayama*
- **Vriddhavastha (Geriatric / > 70 years):** Marked by natural *Vata* dominance and tissue degeneration (*Dhatu Kshaya*). Heavy exercise is strictly prohibited to prevent injury. [14, 18]

Desha (Habitat/Environment)

- **Anupa Desha** (Marshy/Humid/Lush regions): Kapha dominates the environment, yielding better baseline endurance but higher chances of water retention.
- **Jangala Desha** (Arid/Desert regions): Vata and Pitta dominate, making the body inherently drier and more prone to rapid exhaustion. Ardha Shakti Vyayama is reached much sooner.
- **Sadharana Desha** (Temperate/Balanced regions): Ideal conditions where capacity matches standard internal markers. [14]

Ahara (Diet and Nutrition)

- **Snigdha & Madhura Ahara:** Individuals who regularly consume nourishing, unctuous (healthy fats), and rich foods build strong Mamsa (muscle) and Meda (fat) tissues, fueling longer workouts.
- **Ruksha Ahara:** A diet lacking fats or vital nutrients leads to tissue dryness, bringing on the signs of Ardha Shakti (like dry mouth) rapidly. Exercises right after meals are strictly forbidden. [16, 18]

7. LIMITATIONS

The article's *Ardha Shakti* framework lacks objective, standardized, and empirical validation in high-performance sports. Key limitations include reliance on subjective diagnostics, potential performance plateauing, environmental confounding factors, and difficulties integrating traditional concepts with modern biometric data

1. Subjective Variance and Quantification Challenges

Modern athletic training requires precise, objective numbers to calculate training volume, intensity, and progressive overload (e.g., Target Heart Rate zones, VO_2 max scores, Blood Lactate curves, and Power Output wattages) . *Ardha Shakti* relies extensively on subjective sensory feedback (e.g., feeling the air reach the mouth, or experiencing oral dryness).

2. Adaptation and the Principle of Progressive Overload

Elite athletic performance relies on the principle of *supercompensation*—deliberately pushing the body past its current comfort threshold into a temporary state of functional overreaching. This mild stress triggers adaptations that increase baseline performance metrics [20]. Strictly stopping at *Ardha Shakti* (half capacity) every single day may prevent overtraining completely, but it can limit an elite athlete's ability to trigger the deeper genetic, mitochondrial, and metabolic adaptations required to break world records or achieve elite-level athletic conditioning.

3. Confounding Environmental Factors

The classical indicators of *Ardha Shakti*, such as *Sweda Pravritti* (sweating) and *Mukha Shosha* (dry mouth), are easily influenced by external variables independent of actual physical work. For instance, exercising in a highly humid or hot climate triggers profuse sweating and oral dryness within minutes, long before the muscular or cardiovascular systems have achieved a true 50% workload. Conversely, exercising in extreme cold or dehydrated indoor conditions can mask sweat onset, potentially misleading an athlete into over-exertion.

4. Lack of Standardization for Diverse Pathologies

While classical texts outline clear contraindications for *Vyayama* (such as individuals suffering from *Kshaya* [wasting], *Shwasa* [asthma], or *Kasa* [chronic cough]), the *Ardha Shakti* framework lacks specific standardization for people managing modern metabolic and structural issues, including type 1 diabetes, specific cardiac arrhythmias, or complex post-viral fatigue syndromes

8. CLINICAL RECOMMENDATIONS: INTEGRATING ANCIENT WISDOM WITH MODERN TRAINING ARCHITECTURE

1. Digital Mapping of *Ardha Shakti* Indicators

Athletes can wear modern biometrics tracking devices to establish exactly where their Ayurvedic markers appear [12]:

- Monitor the exact Heart Rate (HR) and power output the moment *Hrid-Avastha Prana Vayu* (the shift to oral breathing) occurs [3]. This generally corresponds to the green cardiovascular zone (Zone 2/3), ideal for mitochondrial biogenesis and fat oxidation [20].
- Record Heart Rate Variability (HRV) each morning [19]. A sharp drop in HRV signifies *Vata* vitiation and *Ojas* depletion, indicating the athlete should reduce their training volume well below their usual *Ardha Shakti* limits for that day [15, 19].

2. Seasonal and Prakruti Periodization

Coaches should systematically alter seasonal training blocks to match environmental rhythms (*Ritucharya*) [3]:

- Schedule heavy volume and intense resistance loading during high-strength winter months (*Hemanta* and *Shishira*), providing adequate nutritional support (*Snigdha Ahara*) [3, 13].
- Transition to lower-intensity, restorative, and aerobic maintenance blocks during hot summer months (*Grishma*), shifting the focus toward recovery and flexibility to prevent heat-induced *Pitta* inflammation and oxidative damage [10, 14].

3. Rasayana and Antioxidant Supplementation

To protect the body's vital essence (*Ojas*) from exercise-induced free radicals, the daily diet should include specific Ayurvedic herbs known for their adaptogenic and antioxidant properties (*Rasayana*) [1, 16].

- **Ashwagandha (*Withania somnifera*):** Proven to modulate cortisol levels, stabilize *Vata Dosha*, and protect skeletal muscle from oxidative carbonylation [16].
- **Amalaki (*Emblica officinalis*):** A potent source of heat-stable Vitamin C and polyphenols that neutralizes ROS, boosts mitochondrial efficiency, and preserves tissue metabolic fire (*Dhatu Agni*) [11, 17].

9. CONCLUSION

Ayurvedic exercise physiology provides a sophisticated framework for sustainable physical conditioning. The doctrine of *Ardha Shakti* serves as an intuitive bio-feedback tool that closely matches modern cardiorespiratory and metabolic thresholds. By recognizing early systemic stress signals—such as shifts in breathing patterns, specific sweating zones, and oral dryness—this

framework prevents practitioners from slipping into the catabolic trap of overtraining syndrome and severe oxidative stress.

While certain limitations exist regarding objective quantification in competitive sports settings, integrating *Ardha Shakti* indicators with modern heart rate and metabolic tracking creates a balanced, highly personalized model for health, performance, and long-term vitality.

10. CONFLICTS OF INTEREST:- No

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