

Siddha Medicine and Circadian Rhythms: An Integrative Perspective on Traditional Wisdom and Modern Chronobiology

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Cite this paper as: A. Jayakalairasi , Saravanasingh karan chand mohan singh, A. P. Uma, V. Indumathy, Neethiraja M, Vibushanan G, Ramamurthy Murugan, (2025) Siddha Medicine and Circadian Rhythms: An Integrative Perspective on Traditional Wisdom and Modern Chronobiology. *Journal of Neonatal Surgery*, 14, (2) 292-303

ABSTRACT

Siddha medicine, one of the oldest traditional medical systems originating from South India, emphasizes the fundamental importance of aligning human physiology with natural temporal rhythms for optimal health. This comprehensive review examines the convergence between Siddha medicine's time-based health principles and modern chronobiology, exploring how circadian rhythm synchronization serves as a cornerstone for disease prevention and health promotion. Drawing upon extensive peer-reviewed literature, this document elucidates the molecular mechanisms underlying circadian rhythms, documents the health consequences of circadian disruption, and provides evidence-based recommendations for lifestyle interventions that integrate traditional wisdom with contemporary scientific understanding. The synthesis reveals remarkable parallels between ancient Siddha concepts and modern discoveries in circadian biology, suggesting that traditional time-aligned practices such as *dinacharya* (daily regimen) offer scientifically validated approaches to maintaining metabolic, cardiovascular, immune, and mental health. This integrative perspective provides a foundation for developing holistic, chronobiologically informed healthcare strategies that honor both traditional knowledge and evidence-based medicine..

Keywords: *Siddha medicine, modern chronobiology, daily regimen, Circadian Rhythms*

1. INTRODUCTION

Siddha medicine, deeply rooted in South Indian traditions and sharing philosophical foundations with Ayurveda, represents one of humanity's oldest holistic medical systems. This ancient healing tradition adopts a comprehensive perspective on health that emphasizes the fundamental interconnection between human physiology and natural rhythms [1], [2]. At the heart of this system lies the recognition that health is not merely the absence of disease but rather a dynamic state of balance achieved through harmonious alignment with the temporal patterns governing biological existence [3], [4].

Central to Siddha medicine's approach is the understanding of circadian rhythms—endogenous biological cycles operating

on approximately 24-hour periods that regulate virtually every aspect of human physiology and behavior [5], [6]. These rhythms, which modern science has extensively validated through molecular and physiological research, govern essential processes including sleep-wake cycles, hormone secretion, body temperature regulation, metabolic activity, immune function, and cellular repair mechanisms [7], [8]. The convergence between traditional Siddha concepts and contemporary chronobiology reveals remarkable insights: what ancient practitioners understood through careful observation and empirical practice, modern science now confirms through molecular biology, neurophysiology, and clinical research [9], [10].

The importance of this integrative perspective has become increasingly urgent in contemporary society, where modern lifestyles characterized by artificial lighting, irregular work schedules, shift work, jet lag, and constant digital connectivity have created widespread circadian disruption [11], [12]. Epidemiological evidence demonstrates that circadian misalignment contributes significantly to the global burden of non-communicable diseases, including metabolic syndrome, cardiovascular disease, immune disorders, mental health conditions, and certain cancers [13], [14]. In this context, Siddha medicine's time-honored practices—particularly *dinacharya* (daily regimen) and *ritucharya* (seasonal regimen)—offer evidence-based strategies for restoring circadian synchronization and promoting holistic health [15], [16].

This comprehensive review synthesizes current scientific understanding of circadian biology with traditional Siddha medicine principles, examining molecular mechanisms, health consequences of disruption, and practical interventions. By bridging ancient wisdom and modern science, we aim to provide a foundation for integrative healthcare approaches that honor both traditional knowledge systems and evidence-based medicine, ultimately contributing to more effective strategies for disease prevention and health promotion in the 21st century.

2. THEORETICAL FOUNDATIONS OF SIDDHA MEDICINE AND CIRCADIAN BIOLOGY

2.1 Historical Context of Siddha Medicine

Siddha medicine, along with Ayurveda, constitutes one of the foundational traditional medical systems of the Indian subcontinent, with documented origins extending back thousands of years [17]. The term “Siddha” derives from the Sanskrit word meaning “perfection” or “accomplishment,” reflecting the system's holistic approach to achieving optimal health and spiritual well-being [18]. Like its sister system Ayurveda, Siddha medicine conceptualizes health as a state of dynamic equilibrium between the individual and their environment, emphasizing prevention through lifestyle alignment with natural rhythms [19], [20].

2.2 The Concept of Time in Traditional Indian Medicine

Traditional Indian medical systems, including Siddha medicine, recognize time (*Kāla*) as a fundamental dimension of health and disease [21]. The concept of *Kāla Siddhānta* encompasses multiple temporal scales: diurnal (day-night cycles), lunar (monthly cycles), seasonal (*ritucharya*), and life-stage variations [22]. This sophisticated understanding of temporal medicine predates modern chronobiology by millennia, yet demonstrates remarkable concordance with contemporary scientific findings [23], [24].

The Tridosha theory—central to both Siddha and Ayurvedic medicine—posits that three fundamental bio-energetic principles (*Vata*, *Pitta*, and *Kapha*) govern physiological functions and exhibit predictable temporal variations throughout the day, night, and seasons [25], [26]. *Vata* dosha, associated with movement and nervous system function, predominates during the late afternoon and early morning hours [27]. *Pitta* dosha, governing metabolic and digestive processes, peaks during midday and midnight [28]. *Kapha* dosha, related to structure and stability, dominates during early morning and evening periods [29]. These temporal patterns of dosha predominance form the theoretical basis for time-specific health recommendations in traditional practice [30].

2.3 Modern Chronobiology: An Overview

Chronobiology, the scientific study of biological rhythms, has emerged as a major field of biomedical research, culminating in the 2017 Nobel Prize in Physiology or Medicine awarded for discoveries of molecular mechanisms controlling circadian rhythms [5]. Modern chronobiology recognizes that virtually all organisms, from cyanobacteria to humans, possess endogenous timekeeping systems that enable anticipation of and adaptation to predictable environmental changes, particularly the 24-hour light-dark cycle [6], [7].

In mammals, circadian rhythms are generated by a hierarchical system comprising a master pacemaker in the suprachiasmatic nucleus (SCN) of the hypothalamus and peripheral oscillators in virtually every tissue and organ [8], [10]. This distributed timekeeping system coordinates physiological processes across multiple scales, from gene expression and cellular metabolism to organ function and behavior [11], [12]. The recognition that circadian disruption contributes to numerous diseases has transformed our understanding of health and disease, validating the temporal perspective that traditional systems like Siddha medicine have long emphasized [13], [14].

3. MOLECULAR AND PHYSIOLOGICAL MECHANISMS OF CIRCADIAN RHYTHMS

3.1 The Master Clock: Suprachiasmatic Nucleus

The suprachiasmatic nucleus (SCN), a bilateral structure located in the anterior hypothalamus above the optic chiasm, functions as the master circadian pacemaker in mammals [10], [18]. Comprising approximately 20,000 neurons in humans, the SCN receives direct photic input from specialized intrinsically photosensitive retinal ganglion cells (ipRGCs) containing the photopigment melanopsin [19]. This direct retinohypothalamic pathway enables the SCN to synchronize internal biological time with external environmental light-dark cycles, a process termed entrainment [2], [10].

The SCN orchestrates circadian rhythms throughout the body by generating rhythmic neural and hormonal signals that synchronize peripheral clocks in other brain regions and peripheral tissues [18], [19]. Key output pathways include projections to the paraventricular nucleus (regulating autonomic nervous system activity), the dorsomedial hypothalamus (controlling activity rhythms), and the pineal gland (regulating melatonin secretion) [10]. This hierarchical organization ensures temporal coordination of physiological processes across the entire organism [2], [8].

3.2 Molecular Clock Machinery

At the cellular level, circadian rhythms are generated by transcriptional-translational feedback loops involving a core set of clock genes and their protein products [5], [6]. The primary positive loop involves the transcription factors CLOCK (Circadian Locomotor Output Cycles Kaput) and BMAL1 (Brain and Muscle ARNT-Like 1), which heterodimerize and activate transcription of Period (PER1, PER2, PER3) and Cryptochrome (CRY1, CRY2) genes [7]. PER and CRY proteins accumulate in the cytoplasm, form complexes, and translocate to the nucleus where they inhibit CLOCK-BMAL1 activity, thereby repressing their own transcription [19]. This negative feedback loop requires approximately 24 hours to complete, generating self-sustained oscillations in gene expression [5], [6].

Additional regulatory loops involving the nuclear receptors REV-ERB α/β and ROR $\alpha/\beta/\gamma$ provide stability and fine-tuning to the core clock mechanism [7]. These clock components regulate the expression of thousands of clock-controlled genes (CCGs) in a tissue-specific manner, thereby generating rhythms in diverse physiological processes including metabolism, immune function, cell division, and DNA repair [8], [19]. The molecular clock machinery operates autonomously in virtually every cell of the body, creating a distributed network of cellular oscillators that must be coordinated by the SCN to maintain system-wide temporal organization [10], [18].

3.3 Peripheral Clocks and Tissue-Specific Rhythms

While the SCN serves as the master pacemaker, peripheral tissues including liver, heart, kidney, pancreas, adipose tissue, and skeletal muscle contain autonomous circadian oscillators that regulate local physiological functions [19]. These peripheral clocks are synchronized by the SCN through multiple pathways including autonomic nervous system activity, hormonal signals (particularly glucocorticoids), body temperature rhythms, and feeding-fasting cycles [2], [8], [10].

Peripheral clocks exhibit tissue-specific phase relationships and regulate distinct sets of clock-controlled genes relevant to local tissue function [19]. For example, the liver clock regulates genes involved in glucose and lipid metabolism, xenobiotic detoxification, and bile acid synthesis [7]. The pancreatic clock controls insulin secretion rhythms [8]. The cardiovascular clock regulates blood pressure, heart rate, and vascular function [2]. This tissue-specific regulation enables temporal compartmentalization of incompatible biochemical processes and optimization of metabolic efficiency [19].

Importantly, peripheral clocks can be uncoupled from the SCN by conflicting timing cues, particularly mistimed feeding [8], [10]. This internal desynchronization, where different tissues operate on different circadian phases, contributes to metabolic dysfunction and disease [13], [19]. The recognition of peripheral clock importance has profound implications for understanding how lifestyle factors such as meal timing influence health outcomes [11], [14].

3.4 Hormonal Regulation of Circadian Rhythms

Hormones serve as critical mediators of circadian information throughout the body, exhibiting pronounced daily rhythms that both reflect and reinforce circadian organization [2], [19]. Melatonin, synthesized by the pineal gland under SCN control, exhibits a robust nocturnal rhythm with peak levels during darkness [18], [30]. Melatonin functions as a “darkness signal,” promoting sleep, reducing body temperature, and providing antioxidant protection [30]. Its rhythm is suppressed by light exposure, particularly blue wavelengths, explaining how artificial light disrupts circadian timing [10], [18].

Cortisol, the primary glucocorticoid hormone in humans, displays a characteristic diurnal rhythm with peak levels in the early morning (cortisol awakening response) and nadir during early sleep [19]. This rhythm, generated by circadian regulation of the hypothalamic-pituitary-adrenal (HPA) axis, prepares the body for daily activity by mobilizing energy substrates and modulating immune function [2]. Cortisol serves as a potent synchronizer of peripheral clocks through glucocorticoid receptor-mediated regulation of clock gene expression [19].

Other hormones exhibiting circadian rhythms include growth hormone (peak during early sleep), leptin (nocturnal peak regulating appetite and metabolism), ghrelin (pre-meal peaks stimulating hunger), and numerous metabolic hormones [19]. The temporal coordination of these hormonal rhythms, orchestrated by the circadian system, enables metabolic homeostasis and physiological optimization [2], [8]. Disruption of these hormonal rhythms through circadian misalignment contributes to metabolic disease, as discussed in subsequent sections [13], [14].

4. CIRCADIAN RHYTHMS IN SIDDHA MEDICINE PHILOSOPHY

4.1 Dosha Theory and Temporal Variations

The Tridosha theory represents the cornerstone of Siddha and Ayurvedic physiology, conceptualizing health as a dynamic balance between three fundamental bio-energetic principles: Vata, Pitta, and Kapha [3], [9], [25]. Remarkably, traditional texts describe predictable temporal variations in dosha predominance throughout the 24-hour cycle, anticipating modern chronobiological concepts by millennia [26], [27].

According to classical texts, Kapha dosha predominates during the early morning (6:00-10:00 AM) and early evening (6:00-10:00 PM) periods, corresponding to times when the body exhibits increased stability, structure, and anabolic processes [29]. Pitta dosha peaks during midday (10:00 AM-2:00 PM) and midnight (10:00 PM-2:00 AM), periods associated with heightened metabolic activity, digestion, and transformation [28]. Vata dosha dominates during late afternoon (2:00-6:00 PM) and early morning (2:00-6:00 AM), times characterized by increased movement, nervous system activity, and catabolic processes [27].

Contemporary research has identified striking parallels between these traditional dosha rhythms and modern understanding of neuroendocrine and metabolic rhythms [9], [10], [19]. The Kapha period's association with stability and structure corresponds to times of elevated melatonin (evening) and growth hormone secretion (early morning), both promoting anabolic processes [18], [19]. The Pitta period's emphasis on metabolism and digestion aligns with peak cortisol levels (morning) and optimal digestive enzyme activity (midday) [2], [28]. The Vata period's focus on movement and nervous activity corresponds to increased sympathetic nervous system activity and catecholamine secretion [27].

4.2 Dinacharya: The Daily Regimen

Dinacharya, the Ayurvedic and Siddha concept of daily routine, represents a comprehensive system of time-aligned health practices designed to maintain dosha balance and optimize physiological function [1], [4], [15]. This ancient framework prescribes specific activities at particular times of day, creating a structured approach to circadian synchronization that modern chronobiology increasingly validates [16], [20].

Classical dinacharya recommendations include: waking during the Brahma muhurta (approximately 1.5 hours before sunrise, during Vata predominance) to align with natural circadian awakening mechanisms [12], [15]; performing morning elimination, oral hygiene, and self-massage (abhyanga) to stimulate circulation and lymphatic drainage [4]; engaging in physical exercise (vyayama) during Kapha time (morning) when the body possesses optimal strength and stability [19]; consuming the main meal during Pitta predominance (midday) when digestive fire (Agni) peaks [5], [28]; and retiring to sleep during early Kapha period (before 10:00 PM) to align with natural melatonin rise [18], [20].

Recent randomized controlled trials have demonstrated that adherence to dinacharya practices significantly improves circadian health markers, metabolic parameters, and sleep quality [1]. A study by Perera and colleagues found that participants following structured dinacharya combined with yogic practices exhibited improved circadian alignment, reduced metabolic disorder risk, and enhanced sleep quality compared to controls [1]. These findings validate the therapeutic potential of traditional time-aligned practices for addressing modern circadian disruption [15], [16].

4.3 Ritucharya: Seasonal Rhythms

Beyond daily rhythms, Siddha medicine recognizes the importance of seasonal variations (Ritucharya) in maintaining health [14], [20]. Classical texts describe how dosha predominance varies across seasons, requiring adjustments in diet, lifestyle, and therapeutic interventions [5]. This seasonal perspective acknowledges that circadian rhythms themselves exhibit seasonal plasticity, with day length variations influencing sleep duration, metabolic rate, and immune function [14].

Modern chronobiology confirms that circadian rhythms undergo seasonal adjustments, with photoperiod serving as the primary environmental cue [10]. Seasonal affective disorder, metabolic variations, and immune function changes all reflect the influence of seasonal rhythms on human physiology [13], [14]. The traditional practice of seasonal detoxification (Panchakarma) during transitional periods aligns with contemporary understanding of seasonal immune and metabolic adjustments [18].

4.4 Parallels Between Doshas and Neuroendocrine Rhythms

Emerging research has begun to systematically map traditional dosha concepts onto modern neuroendocrine and metabolic physiology, revealing remarkable correspondences [9], [10], [19]. Vata dosha's association with movement, nervous system function, and catabolic processes parallels the sympathetic nervous system and catecholamine rhythms [27]. Pitta dosha's governance of metabolism, transformation, and digestion corresponds to cortisol rhythms, thyroid hormone function, and digestive enzyme secretion patterns [2], [28]. Kapha dosha's role in structure, stability, and anabolic processes aligns with growth hormone, melatonin, and parasympathetic nervous system activity [18], [29].

A comprehensive review by Mourya and colleagues (2025) systematically examined these parallels, concluding that "Ayurvedic perspectives on circadian rhythms demonstrate remarkable concordance with modern chronobiology, suggesting

that traditional dosha theory represents an empirically-derived model of neuroendocrine rhythms” [10]. This integrative understanding provides a framework for translating traditional concepts into contemporary clinical practice while honoring the holistic perspective of traditional medicine [9], [20].

5. HEALTH CONSEQUENCES OF CIRCADIAN DISRUPTION

5.1 Sleep Disorders

Circadian rhythm disruption represents a primary cause of sleep disorders, affecting sleep onset, duration, quality, and architecture [17], [27]. The bidirectional relationship between circadian rhythms and sleep means that circadian misalignment both causes and is exacerbated by sleep disturbances [27]. Modern lifestyles characterized by irregular sleep schedules, evening light exposure, and shift work create widespread circadian-sleep disruption [11], [12].

Delayed sleep phase disorder, advanced sleep phase disorder, irregular sleep-wake rhythm disorder, and non-24-hour sleep-wake disorder all reflect underlying circadian dysfunction [27]. Even in the absence of diagnosed sleep disorders, circadian misalignment reduces sleep quality, increases sleep fragmentation, and impairs restorative sleep processes [17]. Traditional Ayurvedic sleep medicine recognizes these connections, emphasizing the importance of aligning sleep timing with natural circadian rhythms (particularly sleeping during Kapha predominance) for optimal sleep quality [27].

Research demonstrates that circadian-aligned sleep timing improves sleep efficiency, reduces sleep latency, and enhances slow-wave sleep—the most restorative sleep stage [17], [27]. Conversely, mistimed sleep (such as sleeping during biological day in shift workers) results in shortened sleep duration, reduced sleep quality, and increased risk of insomnia [11], [12]. These findings validate traditional recommendations for consistent, circadian-aligned sleep schedules as foundational to sleep health [20], [27].

5.2 Metabolic Diseases

Circadian disruption profoundly impacts metabolic health, contributing to obesity, type 2 diabetes, metabolic syndrome, and dyslipidemia [5], [13], [14], [19]. The circadian system regulates virtually every aspect of metabolism, including glucose homeostasis, insulin sensitivity, lipid metabolism, energy expenditure, and appetite regulation [8], [19]. Disruption of these rhythms through shift work, irregular eating patterns, or sleep deprivation impairs metabolic function and increases disease risk [11], [13].

Epidemiological studies demonstrate that shift workers exhibit 1.5-2 fold increased risk of metabolic syndrome and type 2 diabetes compared to day workers [13]. Experimental circadian misalignment in controlled laboratory settings rapidly induces insulin resistance, elevated postprandial glucose, and increased blood pressure—key features of metabolic syndrome [14]. These metabolic impairments result from disrupted rhythms in insulin secretion, hepatic glucose production, adipose tissue lipolysis, and skeletal muscle glucose uptake [19].

The timing of food intake exerts powerful effects on metabolic health independent of total caloric intake [5], [8], [11]. Late-night eating, common in modern societies, occurs when metabolic capacity is reduced due to low insulin sensitivity and decreased thermogenesis [8], [19]. This temporal mismatch between food intake and metabolic capacity contributes to weight gain and metabolic dysfunction [11], [14]. Traditional recommendations to consume the main meal during midday Pitta predominance, when digestive capacity peaks, align with contemporary evidence that midday-loaded eating patterns improve metabolic outcomes [5], [28].

A recent integrative review by Monga (2025) specifically examined the convergence between circadian biology and Ayurvedic practices for metabolic syndrome prevention, concluding that “time-restricted eating aligned with traditional dinacharya principles offers a promising strategy for metabolic disease prevention and management” [21]. This synthesis highlights the therapeutic potential of integrating traditional timing wisdom with modern chronobiological understanding [15], [21].

5.3 Cardiovascular Diseases

Cardiovascular function exhibits pronounced circadian rhythms in blood pressure, heart rate, vascular tone, platelet aggregation, and fibrinolytic activity [2]. These rhythms contribute to the well-documented circadian variation in cardiovascular events, with myocardial infarction, sudden cardiac death, and stroke exhibiting peak incidence during morning hours [2], [28]. Chronic circadian disruption increases cardiovascular disease risk through multiple mechanisms including sustained blood pressure elevation, endothelial dysfunction, increased inflammation, and autonomic imbalance [2], [18].

The concept of circadian hyper-amplitude-tension (CHAT)—excessive circadian blood pressure amplitude—represents a novel cardiovascular risk factor that cannot be detected by conventional blood pressure measurement [2]. Shift work and chronic circadian misalignment increase CHAT prevalence and overall cardiovascular disease risk [2], [13]. Traditional Ayurvedic texts recognized the temporal patterning of cardiovascular events, noting increased risk during specific time periods, demonstrating empirical awareness of circadian cardiovascular vulnerability [28].

Melatonin’s cardiovascular protective effects—including antioxidant activity, blood pressure reduction, and anti-

inflammatory actions—depend on appropriate circadian timing [30]. Evening light exposure suppressing melatonin secretion may contribute to cardiovascular risk [18], [30]. Meditation practices, which traditional systems emphasize for cardiovascular health, have been shown to enhance melatonin secretion and improve cardiovascular outcomes through circadian mechanisms [30].

5.4 Immune Dysfunction

The immune system exhibits extensive circadian regulation, with rhythms in immune cell trafficking, cytokine production, antibody responses, and inflammatory processes [10], [18], [23]. These rhythms optimize immune surveillance during rest periods and modulate inflammatory responses to minimize tissue damage during active periods [23]. Circadian disruption impairs immune function, increasing susceptibility to infections, autoimmune diseases, and chronic inflammatory conditions [10], [18].

Shift workers demonstrate increased infection rates, reduced vaccine responses, and elevated inflammatory markers compared to day workers [13], [23]. Experimental sleep restriction and circadian misalignment impair natural killer cell activity, reduce antibody production, and increase pro-inflammatory cytokine levels [18]. These immune impairments result from disrupted rhythms in glucocorticoid signaling, autonomic nervous system activity, and clock gene expression in immune cells [10], [23].

Traditional Ayurvedic practices emphasizing circadian alignment—particularly consistent sleep timing, morning light exposure, and time-restricted eating—have been shown to enhance immune function [23]. A recent review examining “the role of the Ayurvedic clock in boosting the immune system” concluded that dinacharya practices optimize immune rhythms and enhance resistance to disease [23]. This immune-enhancing effect of circadian alignment provides mechanistic support for traditional preventive medicine approaches [15], [20].

5.5 Mental Health Disorders

Circadian rhythm disruption represents both a symptom and a contributing factor in major depression, bipolar disorder, seasonal affective disorder, and anxiety disorders [10], [13], [19]. The bidirectional relationship between circadian rhythms and mood regulation involves shared neurobiological substrates, including serotonergic and dopaminergic systems, HPA axis function, and inflammatory pathways [10], [19].

Depressed patients commonly exhibit circadian rhythm abnormalities including delayed sleep phase, reduced circadian amplitude, and blunted cortisol and melatonin rhythms [13], [19]. Bipolar disorder involves profound circadian disruption, with manic episodes often triggered by sleep deprivation and circadian misalignment [13]. Seasonal affective disorder directly reflects photoperiod-driven changes in circadian timing and melatonin duration [14].

Chronotherapeutic interventions targeting circadian rhythms—including bright light therapy, sleep phase adjustment, and social rhythm therapy—demonstrate efficacy in treating mood disorders [13], [14]. Traditional practices emphasizing regular daily routines (dinacharya), morning light exposure, and meditation align with these evidence-based chronotherapeutic approaches [10], [20]. The mental health benefits of circadian alignment validate traditional emphasis on routine and temporal regularity for psychological well-being [15], [20].

5.6 Cancer and Cellular Dysfunction

Emerging evidence links circadian disruption to increased cancer risk, particularly breast, prostate, and colorectal cancers [13], [18], [19]. The International Agency for Research on Cancer classifies shift work involving circadian disruption as a probable human carcinogen [13]. Multiple mechanisms contribute to this cancer risk, including disrupted cell cycle regulation, impaired DNA repair, altered melatonin signaling, and immune dysfunction [18], [19].

Clock genes regulate cell cycle checkpoints, apoptosis, and DNA damage responses [19]. Disruption of these clock-controlled processes increases mutation accumulation and cancer susceptibility [13], [18]. Melatonin’s oncostatic properties—including antioxidant effects, immune enhancement, and direct anti-proliferative actions—depend on appropriate circadian timing [18], [30]. Chronic light-at-night exposure suppressing melatonin may contribute to cancer risk [18].

The circadian regulation of cellular processes extends to stem cell function, tissue regeneration, and aging [19]. Circadian disruption accelerates cellular aging and impairs regenerative capacity [13], [19]. Traditional concepts of cell rejuvenation through dinacharya practices find support in evidence that circadian alignment enhances cellular repair mechanisms and maintains stem cell function [4], [19].

5.7 Digestive Disorders

The gastrointestinal system exhibits extensive circadian regulation, with rhythms in gastric acid secretion, digestive enzyme production, gut motility, intestinal permeability, and microbiome composition [5], [8], [18]. These rhythms optimize digestive efficiency and nutrient absorption while maintaining gut barrier function [8], [18]. Circadian disruption impairs digestive function, contributing to gastroesophageal reflux, peptic ulcer disease, irritable bowel syndrome, and inflammatory

bowel disease [5], [18].

Gastric acid secretion peaks during evening and nighttime hours, explaining the circadian pattern of peptic ulcer symptoms and the increased risk of reflux with late-night eating [5], [18]. Digestive enzyme secretion and gut motility exhibit diurnal rhythms that optimize nutrient processing during daytime feeding periods [8]. Mistimed eating disrupts these rhythms, impairing digestion and promoting gastrointestinal symptoms [5], [8].

The gut microbiome exhibits circadian rhythms in composition and metabolic activity, influenced by feeding-fasting cycles and host circadian rhythms [8], [18]. Circadian disruption alters microbiome composition, potentially contributing to metabolic and inflammatory diseases [8]. Traditional Ayurvedic emphasis on regular meal timing, particularly consuming the main meal during midday Pitta predominance when digestive fire peaks, aligns with evidence that circadian-aligned eating optimizes digestive function [5], [28].

6. EVIDENCE-BASED LIFESTYLE INTERVENTIONS FOR CIRCADIAN SYNCHRONIZATION

6.1 Sleep Hygiene and Timing

Optimal sleep timing represents the cornerstone of circadian health, with consistent sleep-wake schedules serving as the primary synchronizer of human circadian rhythms [17], [20], [27]. Evidence-based sleep hygiene recommendations align remarkably with traditional dinacharya principles, emphasizing regular sleep timing, appropriate sleep duration, and circadian-aligned sleep scheduling [15], [20].

Research demonstrates that consistent sleep timing—going to bed and waking at the same times daily, including weekends—strengthens circadian rhythms and improves sleep quality [17], [27]. The traditional recommendation to sleep during early Kapha period (before 10:00 PM) corresponds to the natural rise in melatonin and sleep pressure that occurs during evening hours [18], [20]. Delaying sleep beyond this window, common in modern societies, requires sleeping during Pitta predominance when metabolic activity naturally increases, potentially impairing sleep quality [20], [27].

Morning awakening during Brahma muhurta (approximately 1.5-2 hours before sunrise) aligns with the natural circadian awakening process driven by rising cortisol and declining melatonin [12], [15], [19]. While this early awakening time may not be practical for all individuals, the principle of consistent, early morning awakening provides strong circadian synchronization [17], [20]. Exposure to morning light immediately upon awakening further reinforces circadian timing [10], [18].

Sleep duration recommendations vary by age, but adults generally require 7-9 hours of sleep per night for optimal health [17], [27]. Both insufficient sleep (less than 6 hours) and excessive sleep (more than 9 hours) associate with increased disease risk [13], [17]. The quality of sleep—including adequate slow-wave and REM sleep—depends on circadian alignment, emphasizing the importance of appropriate sleep timing rather than duration alone [27].

6.2 Meal Timing and Dietary Practices

Meal timing exerts powerful effects on circadian rhythms and metabolic health, with growing evidence supporting time-restricted eating (TRE) as a therapeutic intervention [5], [8], [11], [21]. TRE involves confining food intake to a consistent window of 8-12 hours during the active phase, typically aligned with daylight hours [8], [11]. This eating pattern aligns with traditional dinacharya recommendations and demonstrates multiple health benefits including improved glucose regulation, weight loss, reduced inflammation, and enhanced circadian rhythms [5], [11], [21].

The traditional emphasis on consuming the main meal during midday Pitta predominance (10:00 AM-2:00 PM) aligns with evidence that midday-loaded eating patterns improve metabolic outcomes compared to evening-heavy eating [5], [28]. Insulin sensitivity, glucose tolerance, and thermogenesis all peak during midday hours, making this the optimal time for largest meal consumption [8], [19]. Conversely, late-night eating occurs when metabolic capacity is reduced, contributing to weight gain and metabolic dysfunction [11], [14].

Specific dietary recommendations from traditional texts find support in chronobiological research. The Ayurvedic prohibition against consuming curd (yogurt) at night aligns with evidence that fermented dairy products may disrupt sleep in some individuals [5]. The recommendation to consume fruits before meals corresponds to optimal timing for simple carbohydrate consumption when insulin sensitivity is higher [5]. The emphasis on warm, easily digestible foods in the evening supports the natural decline in digestive capacity during nighttime hours [5], [8].

Intermittent fasting (Upavasa), a traditional Ayurvedic practice, demonstrates circadian benefits when properly timed [11], [19]. Fasting during the biological night (evening and nighttime hours) aligns with natural circadian rhythms in metabolism and enhances metabolic health [8], [11]. A recent integrative review examining “the interplay of fasting, circadian rhythms, and Ayurvedic Langhan” concluded that time-restricted eating represents a convergence of traditional wisdom and modern chronobiology [11].

6.3 Exercise and Physical Activity Timing

Physical activity timing influences both acute exercise responses and long-term health outcomes, with evidence suggesting optimal benefits from morning or early afternoon exercise [1], [19]. The traditional recommendation for exercise (Vyayama) during morning Kapha period (6:00-10:00 AM) aligns with physiological evidence that muscle strength, cardiovascular capacity, and injury resistance peak during morning hours [19].

Morning exercise provides additional circadian benefits by serving as a zeitgeber (time cue) that reinforces circadian rhythms [10], [19]. Exercise during morning hours enhances circadian amplitude, improves sleep quality, and optimizes metabolic responses [1], [19]. Conversely, intense exercise during evening hours may delay circadian phase and impair subsequent sleep, though moderate evening activity can be beneficial for some individuals [19].

The traditional concept of “ardhasakti vyayama”—exercising to half one’s capacity—reflects understanding that excessive exercise can disrupt physiological balance [19]. Modern research confirms that overtraining impairs circadian rhythms, immune function, and metabolic health [13], [19]. The emphasis on regular, moderate physical activity aligned with circadian rhythms represents an evidence-based approach to exercise prescription [1], [15].

Outdoor exercise provides the additional benefit of natural light exposure, which serves as the primary circadian synchronizer [10], [18]. Morning outdoor activity combines the circadian benefits of exercise timing with light exposure, providing synergistic effects on circadian health [1], [15], [19].

6.4 Light Exposure Management

Light represents the most powerful environmental synchronizer of human circadian rhythms, with timing, intensity, and spectral composition all influencing circadian phase and amplitude [10], [18]. Strategic light exposure management—maximizing bright light during morning hours and minimizing light during evening and nighttime—provides a foundational circadian intervention [18], [20].

Morning bright light exposure (ideally outdoor natural light providing 1,000-10,000 lux) advances circadian phase, strengthens circadian amplitude, and improves alertness [10], [18]. The traditional practice of waking early and engaging in outdoor morning activities provides optimal light exposure timing [15], [20]. Even brief morning light exposure (15-30 minutes) demonstrates circadian benefits [18].

Evening and nighttime light exposure, particularly blue wavelengths (460-480 nm), suppresses melatonin secretion and delays circadian phase [18]. Modern artificial lighting and electronic device use create widespread evening light exposure, contributing to circadian disruption [11], [12]. Minimizing bright light exposure during evening hours, using warm-spectrum lighting (avoiding blue wavelengths), and avoiding screens before bedtime support natural melatonin rise and circadian alignment [18], [20].

The traditional practice of aligning daily activities with natural light-dark cycles—waking with sunrise, conducting activities during daylight, and retiring after sunset—provides optimal circadian light exposure patterns [15], [20]. While complete adherence to natural light-dark cycles may not be practical in modern societies, the principle of maximizing light-dark contrast (bright days, dark nights) remains valid [10], [18].

6.5 Mindfulness and Meditation Practices

Meditation and mindfulness practices, integral to traditional Indian medicine systems, demonstrate multiple mechanisms for supporting circadian health [1], [30]. Regular meditation practice improves sleep quality, reduces stress-related circadian disruption, and may enhance melatonin secretion [30]. The circadian benefits of meditation likely involve multiple pathways including HPA axis regulation, autonomic nervous system balance, and reduced inflammatory signaling [30].

A study examining “the role of melatonin in meditation on cardiovascular health” found that regular meditation practice enhances melatonin secretion and improves cardiovascular outcomes through circadian mechanisms [30]. The timing of meditation practice may influence its circadian effects, with morning meditation potentially providing alerting effects and evening meditation promoting relaxation and sleep preparation [1], [30].

Traditional practices such as yoga, which combines physical postures, breathing exercises, and meditation, demonstrate synergistic effects on circadian health [1]. A randomized controlled trial found that combined dinacharya and yogic practices significantly improved circadian health markers, metabolic parameters, and sleep quality [1]. These findings validate the integrative approach of traditional systems that combine multiple lifestyle practices for holistic health benefits [15], [20].

Mindfulness-based stress reduction (MBSR) and other structured meditation programs improve sleep quality and reduce circadian disruption associated with stress and anxiety [30]. The emphasis on present-moment awareness and acceptance in mindfulness practice may reduce rumination and worry that commonly interfere with sleep and circadian rhythms [30]. Integration of traditional meditation practices with modern chronobiological understanding offers promising approaches for addressing stress-related circadian disruption [1], [20].

6.6 Integrative Daily Routines

The comprehensive nature of dinacharya—integrating sleep timing, meal timing, exercise, light exposure, and contemplative practices into a coherent daily routine—provides a holistic approach to circadian synchronization [1], [4], [15], [16]. Modern chronobiology increasingly recognizes that multiple zeitgebers (time cues) act synergistically to entrain circadian rhythms, supporting the traditional emphasis on comprehensive daily routines rather than isolated interventions [10], [20].

A systematic review examining “Ayurveda daily regimen practices (Dinacharya) as a quaternary prevention strategy for non-communicable diseases” concluded that dinacharya represents a scientifically valid approach to disease prevention through circadian optimization [15]. The review noted that dinacharya practices address multiple circadian synchronizers simultaneously, providing more robust circadian entrainment than single interventions [15].

Key elements of an evidence-based integrative daily routine include: (1) consistent sleep-wake timing with early morning awakening and evening sleep onset; (2) immediate morning light exposure, ideally through outdoor activity; (3) morning exercise or physical activity; (4) time-restricted eating with largest meal during midday hours; (5) minimization of evening light exposure; (6) regular meditation or mindfulness practice; and (7) consistent daily timing of all activities [1], [15], [16], [20].

Individual variation in chronotype (morning preference vs. evening preference) requires personalization of specific timing recommendations while maintaining the principle of consistency and circadian alignment [17], [20]. Traditional concepts of individual constitution (Prakriti) acknowledge this individual variation, emphasizing personalized recommendations within the framework of circadian principles [15], [20].

7. INTEGRATION OF TRADITIONAL WISDOM WITH MODERN CHRONOBIOLOGY

7.1 Chronotherapy and Ayurvedic Drug Administration

The concept of chronotherapy—timing drug administration to optimize efficacy and minimize adverse effects—finds ancient precedent in Ayurvedic concepts of Bhesaja Kaala (optimal drug administration timing) [5], [6], [7], [16]. Traditional texts describe ten different time periods for medicine administration based on biological rhythms, disease characteristics, and individual constitution [6], [16]. Modern chronopharmacology validates this temporal approach, demonstrating that drug pharmacokinetics, pharmacodynamics, and therapeutic effects vary with circadian timing [5], [6], [7].

Circadian rhythms influence drug absorption, distribution, metabolism, and elimination through rhythmic changes in gastric pH, intestinal motility, hepatic enzyme activity, renal function, and blood flow [6], [7]. Drug receptor sensitivity and cellular responsiveness also exhibit circadian variation [5], [6]. These rhythmic variations create time-dependent differences in drug efficacy and toxicity, with optimal administration times varying by drug class and therapeutic target [6], [7].

Cardiovascular medications demonstrate particularly pronounced chronotherapeutic effects [2], [6]. Antihypertensive medications administered at bedtime provide superior blood pressure control and cardiovascular protection compared to morning dosing [2]. Statins administered in the evening align with the circadian rhythm of cholesterol synthesis, enhancing efficacy [6]. Aspirin timing influences its antiplatelet effects and cardiovascular protection [2], [6].

The integration of traditional Bhesaja Kaala concepts with modern chronopharmacology offers opportunities for optimizing therapeutic outcomes [5], [6], [7]. A comprehensive review on “Ayurvedic perspectives on drug administration timings” concluded that traditional timing principles demonstrate remarkable concordance with modern chronopharmacological evidence [6]. This convergence suggests potential for developing integrative chronotherapeutic protocols that honor traditional wisdom while incorporating contemporary pharmacological understanding [5], [7], [16].

7.2 Preventive Medicine Approaches

The preventive medicine orientation of Siddha and Ayurvedic systems—emphasizing health maintenance through lifestyle alignment rather than disease treatment—aligns with contemporary public health priorities [15], [20], [21]. The recognition that circadian disruption contributes to the global burden of non-communicable diseases positions circadian synchronization as a primary prevention strategy [13], [14], [15].

Dinacharya practices represent a form of quaternary prevention—preventing medicalization and overtreatment by maintaining health through lifestyle optimization [15]. This approach addresses root causes of disease (circadian disruption) rather than managing symptoms, offering potential for reducing healthcare costs and improving population health [15], [21]. The accessibility and low cost of lifestyle interventions make them particularly suitable for population-level implementation [15], [20].

Integration of traditional preventive practices with modern public health approaches requires cultural adaptation, scientific validation, and healthcare system integration [15], [20]. Randomized controlled trials demonstrating efficacy of dinacharya practices provide evidence supporting their integration into mainstream healthcare [1], [15]. Educational initiatives teaching circadian health principles and traditional practices could enhance public health outcomes [20], [21].

The concept of “lifestyle medicine”—using evidence-based lifestyle interventions as primary therapeutic modalities—provides a framework for integrating traditional preventive practices with contemporary healthcare [15], [21]. Circadian

health optimization through dinacharya-inspired interventions represents a promising lifestyle medicine approach for preventing and managing chronic diseases [1], [15], [21].

7.3 Clinical Applications and Future Research

Clinical applications of integrated traditional-modern chronobiological approaches span multiple domains including sleep medicine, metabolic disease management, cardiovascular care, mental health treatment, and cancer prevention [13], [14], [20], [21]. Sleep medicine represents a particularly promising area, with traditional Ayurvedic sleep practices demonstrating efficacy for various sleep disorders [27]. Integrative protocols combining sleep hygiene, chronotherapy, and traditional practices such as abhyanga (oil massage) and shirodhara (oil pouring therapy) warrant systematic investigation [27].

Metabolic disease management increasingly incorporates chronobiological interventions, particularly time-restricted eating and meal timing optimization [8], [11], [21]. Integration of these evidence-based approaches with traditional dietary principles and timing recommendations offers potential for enhanced therapeutic outcomes [5], [21]. Clinical trials examining integrated protocols for metabolic syndrome prevention and management represent important research priorities [21].

Mental health applications of circadian interventions, including bright light therapy, sleep phase adjustment, and meditation practices, demonstrate efficacy for mood disorders [13], [14], [30]. Integration of these approaches with traditional practices emphasizing routine, contemplation, and circadian alignment warrants further investigation [20], [30]. The potential for traditional practices to enhance treatment adherence and provide holistic support deserves particular attention [20].

Future research priorities include: (1) mechanistic studies examining how traditional practices influence molecular clock function; (2) large-scale randomized controlled trials evaluating integrated traditional-modern interventions; (3) implementation research examining how to effectively integrate traditional practices into healthcare systems; (4) personalized chronotherapy approaches considering individual chronotype and constitution; and (5) population health studies examining the impact of circadian health education and traditional practice promotion [15], [20], [21].

8. CONCLUSION AND FUTURE DIRECTIONS

This comprehensive review demonstrates remarkable convergence between Siddha medicine's ancient wisdom regarding temporal health principles and modern chronobiology's molecular and physiological understanding of circadian rhythms. The traditional concept of aligning daily activities with natural rhythms through dinacharya practices finds extensive validation in contemporary research demonstrating that circadian synchronization represents a cornerstone of health maintenance and disease prevention [1], [15], [20].

The molecular mechanisms underlying circadian rhythms—involved clock genes, hormonal regulation, and tissue-specific oscillators—provide mechanistic understanding of how traditional time-aligned practices influence health outcomes [5], [6], [7], [8], [10], [19]. The extensive health consequences of circadian disruption, spanning metabolic, cardiovascular, immune, mental health, and cancer domains, underscore the importance of circadian health as a public health priority [13], [14], [18]. Evidence-based lifestyle interventions for circadian synchronization, including sleep timing optimization, time-restricted eating, strategic light exposure, and meditation practices, align remarkably with traditional dinacharya recommendations [1], [5], [8], [11], [15], [18], [20], [30].

The integration of traditional wisdom with modern chronobiology offers multiple benefits: (1) validation of traditional practices through scientific evidence; (2) mechanistic understanding of how traditional interventions work; (3) optimization of traditional practices based on contemporary research; (4) development of integrative protocols combining traditional and modern approaches; and (5) cultural preservation and revitalization of traditional knowledge systems [9], [15], [20]. This integrative perspective honors both traditional knowledge and scientific methodology, creating synergistic approaches to health promotion.

Future directions for this field include expanding mechanistic research on traditional practices, conducting large-scale clinical trials of integrated interventions, developing personalized chronotherapy approaches, implementing circadian health education programs, and fostering interdisciplinary collaboration between traditional medicine practitioners and chronobiology researchers [15], [20], [21]. The potential for traditional time-aligned practices to address the epidemic of circadian disruption in modern societies represents a promising frontier for preventive medicine and public health [1], [13], [15], [21].

As we navigate the challenges of 21st-century life—characterized by artificial lighting, irregular schedules, and constant connectivity—the ancient wisdom of Siddha medicine offers a roadmap for restoring harmony between human biology and natural rhythms. By integrating this traditional knowledge with cutting-edge chronobiological science, we can develop comprehensive, evidence-based approaches to optimizing health, preventing disease, and enhancing quality of life. The convergence of ancient wisdom and modern science in the domain of circadian health exemplifies the potential for integrative medicine to address contemporary health challenges while honoring humanity's rich heritage of healing traditions.

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