

# The Correlation Between Circadian Rhythms and Chronic Kidney Disease and Traditional Chinese Medicine Approaches to Prevention and Treatment

Zhiqing Li<sup>1</sup>, Xiaohui Li<sup>2,\*</sup>

<sup>1</sup>Shaanxi University of Chinese Medicine, Xianyang 712046, Shaanxi, China

<sup>2</sup>Affiliated Hospital of Shaanxi University of Chinese Medicine, Xianyang 712000, Shaanxi, China

\*Correspondence Author

**Abstract:** *Chronic kidney disease (CKD) has become a global public health issue, necessitating multifaceted approaches to its prevention and management. Contemporary chronobiology reveals that circadian rhythm disruption constitutes a significant risk factor in the onset and progression of CKD. This understanding aligns profoundly with the core principle of traditional Chinese medicine (TCM) known as 'correspondence between heaven and man'. This paper, grounded in TCM theory, systematically elucidates the unity between human physiological and pathological rhythms and the natural world. It proposes that circadian rhythm disruption primarily leads to 'imbalance of yin and yang, and impaired pivotal functions' within the body, thereby impairing the kidney's functions of governing water metabolism and storing essence, accelerating CKD progression. Regarding prevention and treatment, it emphasises the overarching principle of 'following Yin and Yang, harmonising with the arts of timing,' encompassing lifestyle interventions aligned with rhythms, TCM-specific therapies such as time-specific medication administration and acupuncture, and integrating rhythm adjustment into the pattern differentiation and treatment system. This aims to provide novel approaches for CKD prevention and treatment that combine traditional wisdom with modern scientific evidence.*

**Keywords:** Harmony between Heaven and Man, Circadian Rhythm, Chronic Kidney Disease, Balancing Yin and Yang, Preventing Illness Before It Occurs.

## 1. Introduction

The prevalence of chronic kidney disease (CKD) continues to rise globally. Due to its insidious onset, most patients present at an intermediate or advanced stage, with the potential for progression to end-stage renal disease. Current CKD management primarily focuses on controlling traditional risk factors such as blood pressure, blood glucose, and proteinuria. However, disease progression rates remain persistently high [1], indicating an urgent need to explore novel intervention targets rooted in the fundamental rhythms of life processes. Concurrently, advances in modern chronobiology have revealed that the circadian rhythm, as the fundamental biological clock, extensively regulates nearly all physiological processes including the sleep-wake cycle, blood pressure, heart rate, hormone secretion, metabolism, and immune function [2]. Disruption of the circadian rhythm caused by prolonged night-time wakefulness, exposure to artificial light at night, and sleep disorders has been demonstrated to be significantly associated with increased risk of obesity, diabetes, hypertension, cardiovascular disease, and other upstream conditions of CKD. Furthermore, such disruption can directly promote the onset and progression of CKD [3, 4]. This modern scientific discovery aligns remarkably with the concept of 'correspondence between heaven and man' advocated in traditional Chinese medicine for millennia. The Suwen: Treatise on Preserving Life and Maintaining Form states: 'Man is born of the energies of heaven and earth, and shaped by the laws of the four seasons.' Similarly, the Ling Shu: Treatise on the Manifestations of the Seasons asserts: 'Man is intertwined with heaven and earth, and resonates with the sun and moon.' This profoundly reveals the synchronous and unified relationship between human life activities and the natural world's alternation of day and night, and the succession of the four seasons. The internal

fluctuations of yin and yang, the abundance or deficiency of qi and blood, and the functional activities of the zang-fu organs all follow specific temporal rhythms. The kidneys, as the foundation of innate constitution and the organ governing water and fire, harbour primordial yin and yang. Their physiological functions and pathological changes are particularly closely linked to circadian rhythms. Therefore, this paper aims to systematically explore the correlation between circadian rhythm disorders and CKD, along with their pathogenesis and prevention and treatment, based on the theory of 'correspondence between heaven and man'. It seeks to provide new strategies for clinical practice.

## 2. The Intrinsic Unity Between Traditional Chinese Medicine's Theory of Heaven - Human Correspondence and Circadian Rhythm Biology

The concept of "correspondence between heaven and man" constitutes a core tenet of holistic thinking in traditional Chinese medicine. It posits that the human body forms an organic whole, intimately interconnected with the external natural environment. As stated in Ling Shu: The Evil Guest, 'Man corresponds with heaven and earth.' Su Wen: On Preserving Life and Maintaining the Body elaborates further: 'Man is born of the qi of heaven and earth, and shaped by the laws of the four seasons.' This signifies that the vital activities of the human body—including the functions of the zang-fu organs, the circulation of qi and blood, and the waxing and waning of yin and yang—are in close, synchronous resonance with the cyclical transformations of heaven and earth, the four seasons, and the celestial bodies [5]. Among these, the circadian rhythm—a daily cycle where day represents yang and night represents yin—constitutes the most direct and

prominent manifestation of this correspondence between heaven and humanity.

## 2.1 Yin-Yang Rhythms and the Alternation of Day and Night:

The Suwen: Discourses on the Golden Vault states: 'From dawn until noon, the Yang of Heaven is at its zenith; from noon until dusk, the Yang of Heaven is the Yin within Yang; from nightfall until cockcrow, the Yin of Heaven is at its depth; from cockcrow until dawn, the Yin of Heaven is the Yang within Yin.' During the day, the human body's yang energy ascends to the surface, with functions active; at night, it retreats inward to rest and recuperate. This description – 'Yang energy governs the exterior during the day; human vitality arises at dawn, reaches its zenith at noon, and wanes as the sun sets, whereupon the energy gates close' (Suwen: Treatise on Vital Energy Connecting with Heaven) – precisely delineates the diurnal fluctuations in human energy metabolism and immune function. This aligns with the rhythmic variations in cortisol and core body temperature observed in modern physiology.

## 2.2 Circulation of Qi and Blood in Organs and Meridians According to the Hours:

The Zi-Wu Flow Theory correlates the circulation of qi and blood within the Twelve Meridians with the twelve hours of the day, positing that each meridian experiences peak qi and blood activity during its designated hour. The Foot Shaoyin Kidney Meridian corresponds to the You hour (17:00–19:00), signifying that during this period, the physiological functions of the kidneys reach their zenith and may be most responsive to therapeutic interventions [6]. Modern circadian rhythm biology has identified intrinsic transcriptional-translational negative feedback loops at the molecular level, where core clock genes (e.g., CLOCK, BMAL1) and period genes (e.g., Per, Cry) exhibit approximately 24-hour oscillatory expression patterns [7, 8]. These clock genes are present in nearly all tissue cells, forming a hierarchical network extending from the central circadian clock in the suprachiasmatic nucleus (SCN) to peripheral clocks in organs such as the kidneys. Research indicates that the kidneys possess a robust peripheral biological clock, precisely regulating the circadian rhythms of glomerular filtration rate, renal blood flow, reabsorption and excretion of electrolytes (such as sodium and potassium), and blood pressure. For instance, glomerular filtration rate and sodium excretion peak during the active phase (daytime in humans) and reach their lowest levels during the resting phase (night-time), a rhythmicity crucial for maintaining water-salt balance [9]. Thus, Traditional Chinese Medicine's theory of 'correspondence between heaven and man' grasps the temporal attributes of life from a macro-level holistic perspective, while modern chronobiology reveals its material basis at the micro-molecular level. Together, these approaches corroborate the rhythmic nature of life processes from distinct dimensions.

## 3. The Pathogenesis of Circadian Rhythm Disorders Damaging the Kidneys in Traditional Chinese Medicine

Prolonged lifestyles that contravene natural circadian rhythms — such as staying up late, irregular sleep patterns, and nocturnal eating—disrupt the harmony between heaven and humanity. This causes the body's internal rhythms to fall out of sync with the external environment. The Inner Canon of Huangdi describes this as 'going against the root, thereby undermining the foundation and corrupting the true essence'; traditional Chinese medicine terms it 'imbalance of yin and yang'. Such disharmony constitutes a crucial pathogenic mechanism underlying the onset and progression of chronic kidney disease.

### 3.1 Initiation Phase: Imbalance of Yin and Yang, Impairment of Vital Mechanisms

This constitutes the core pathogenesis of disease onset, situated within the stage of functional dysfunction.

3.1.1 Yang fails to enter yin, generating deficient heat internally: Prolonged night-time wakefulness or sustained mental agitation during the night compels yang qi to remain externally hyperactive during the nocturnal period when it should be retreating into yin. This prevents yang from entering yin, resulting in the condition of 'yang failing to enter yin'. Clinically, this typically manifests as difficulty falling asleep at night, restlessness, and tossing and turning. Prolonged Yang hyperactivity inevitably depletes Yin fluids, resulting in 'Yin failing to restrain Yang' and establishing a pathological state of Yin deficiency with excessive fire [10]. As the Kidney houses primordial Yin, it is the first to be affected, manifesting symptoms such as soreness and weakness in the lower back and knees, dry mouth and throat, tidal fevers and night sweats, a red tongue with scant coating, and a fine, rapid pulse. Modern research confirms that circadian rhythm disruption can cause abnormalities in the hypothalamic-pituitary-adrenal (HPA) axis rhythm. This manifests as delayed diurnal peaks or reduced amplitude in cortisol secretion, alongside abnormally elevated nocturnal levels – precisely reflecting the microscopic manifestation of 'yang qi' failing to withdraw at night [11-13]. Persistently elevated cortisol levels not only promote protein catabolism and exacerbate azotemia but also elevate blood pressure and glucose, directly damaging renal function.

3.1.2 Impaired Function of the Shaoyang Hinge Mechanism and Obstruction of the Triple Energiser Waterways: The Foot Shaoyang Gallbladder Meridian and Hand Shaoyang Triple Energiser Meridian are paired as exterior-interior, jointly governing the hinge mechanism that regulates the body's qi movement through ascension, descent, entry, and exit. This function is intrinsically linked to the body's rhythmic regulation. Disruption of these rhythms first disturbs the Shaoyang hinge mechanism, leading to qi stagnation. The Triple Energiser is termed the 'Officer of the Waterways, through which fluids flow', serving as the conduit for fluid circulation. When the Shao Yang pivot mechanism is impaired, the Triple Energiser's fluid transformation ceases, disrupting fluid distribution. Accumulated fluids manifest as dampness, overflowing into the skin to produce oedema; obstruction in the middle jiao leads to loss of appetite and epigastric fullness. This exacerbates the fluid metabolism burden in CKD patients.

### 3.2 Progression Phase: Internal Accumulation of Turbid Toxins, Impaired Kidney Storage Function

At this stage, pathological products begin to accumulate, impairing the kidneys' inherent capacity for consolidation and storage.

**3.2.1 Impaired Opening and Closing Functions, Leading to the Leakage of Essences:** The kidneys govern water metabolism, with their functions of 'opening' (excreting turbid fluids) and 'closing' (conserving essences) operating according to an intrinsic rhythm. During daytime activity, kidney qi favours 'opening' to accelerate waste elimination; during nighttime rest, it favours 'closing' to reduce urine production, conserve vital essence, and facilitate tissue repair. Rhythm disruption causes disorder in this opening-closing sequence. Failure to close when required at night not only leads to frequent nocturnal urination, severely disrupting sleep quality and blood pressure rhythms, but more critically, may compromise the retention of vital substances such as proteins, resulting in or exacerbating proteinuria [14]. Proteinuria serves not only as a biomarker of glomerular filtration barrier damage but also as an independent risk factor accelerating renal interstitial fibrosis progression.

**3.2.2 Damp-turbidity breeds toxins, damaging the viscera:** When the kidneys' water-regulating function becomes impaired, dampness and fluid retention accumulate internally. Over time, if not resolved, this gives rise to damp-turbidity. When damp-turbidity stagnates and transforms into heat, it may become damp-heat. Accumulating within the body, it obstructs qi circulation, depletes vital energy, and thus transforms into 'turbid toxins'. This 'turbid toxin' constitutes both a pathological product of CKD and a 'secondary pathogenic factor' driving disease progression. It may circulate throughout the body, damaging the five viscera and six bowels, thereby exacerbating the pathological burden on the organism [15].

### 3.3 Terminal Stage: Chronic Disease Penetrates the Collaterals, Leading to Renal Collateral Stasis

This represents the stage of substantial tissue damage, constituting the pivotal pathological transition from CKD to its advanced phase.

'Initially the disease resides in the meridians; prolonged illness invades the collaterals,' and 'prolonged illness often involves stasis.' Non-dipper hypertension arising from disrupted circadian rhythms [16], persistent oxidative stress, and chronic inflammatory states all fall within the categories of 'blood stasis' and 'internal wind' in Traditional Chinese Medicine pattern differentiation. Turbid toxins and blood stasis mutually entangle, becoming stubbornly fixed within the kidney's collaterals. This leads to damage of capillary endothelial cells, microthrombus formation, and tissue ischaemia-hypoxia, ultimately promoting glomerulosclerosis and renal interstitial fibrosis. This pathogenesis of 'turbid toxins and blood stasis mutually entwining to damage the kidney collaterals' represents a traditional Chinese medical interpretation of the common pathway of renal fibrosis in modern pathology.

In summary, circadian rhythm disorders progress through a pathological chain of events: 'imbalance of yin and yang (initiation) → impaired pivotal functions and internal accumulation of pathogenic toxins (progression) → obstruction of kidney collaterals (terminal stage)'. This sequence drives the development and progression of chronic kidney disease (CKD) by advancing from functional disruption to organic damage.

## 4. Prevention and Treatment of CKD Based on the Principle of Heaven-Human Correspondence in Traditional Chinese Medicine

In preventing and treating CKD, it is essential to prioritise restoring and maintaining normal circadian rhythms, thereby achieving harmony through the principles of Yin and Yang and the art of medical practice.

### 4.1 Harmonising with Yin and Yang: Lifestyle Interventions as the Cornerstone

Maintain regular routines and sleep in accordance with the natural rhythm: It is crucial to fall asleep before the Zi hour (23:00–01:00) [6]. During Zi hour, yang energy begins to rise while yin energy peaks. Resting peacefully at this time facilitates the smooth transition of yang energy into yin, enabling profound restoration and the storage of vital essence. Ensure sleep environments are dark and quiet, avoiding nocturnal light exposure (particularly blue light) which suppresses endogenous melatonin secretion [4].

Eat in moderation, with a light supper: Maintain regular meals and avoid late-night snacks. As spleen and stomach function diminishes at night, overly late or heavy suppers increase gastrointestinal and renal burdens, contradicting the principle that 'when the stomach is unsettled, sleep is disturbed.' Follow the guideline of 'eat well at breakfast, eat sufficiently at lunch, eat lightly at supper,' opting for easily digestible, low-protein, and low-salt foods for the evening meal.

Engage in moderate exercise in accordance with the time of day: During daylight hours, undertake gentle aerobic activities such as walking, Tai Chi, or the Eight Brocades to aid the rise of yang energy and improve qi and blood circulation. However, strenuous exercise should be avoided after dusk to prevent disturbing the yang energy and disrupting night-time rest [17]. Concurrently, one should adjust daily routines according to seasonal climatic patterns, as advocated in the Suwen: 'Nourish yang in spring and summer; nourish yin in autumn and winter.'

### 4.2 Harmonising with Astrological Techniques: The Timely Application of Traditional Chinese Medicine's Characteristic Therapies

**4.2.1 Timing of Medication Administration:** Selecting the optimal time to take medication based on its properties and the characteristics of the condition can yield twice the result with half the effort.

Tonifying Medications (e.g., Liuwei Dihuang Wan for

nourishing kidney yin; Jinkui Shenqi Wan for warming and tonifying kidney yang): Recommended administration in the morning (aligning with the rising yang energy) or during the You hour (17:00–19:00, when the kidney meridian is most active), leveraging the natural and meridian energies at their peak to enhance tonifying effects [6].

Pathogenic-attacking herbs (e.g., Poria and Polyporus for draining dampness, Rheum for purging intestinal turbidity): It is advisable to take these during daylight hours. This allows the dynamic force of yang qi to expel water, dampness, and turbid pathogens, while avoiding night-time administration which may cause frequent nocturnal urination and disrupt sleep [18].

**4.2.2 Timed Acupuncture/Moxibustion:** Consider acupuncture or moxibustion at the hour of You (7–9 pm) on points such as Shenshu (BL23), Taixi (KI3), Guanyuan (CV4), and Yongquan (KI1) to stimulate the kidney meridian's qi and nourish primordial energy. For those with kidney yang deficiency manifesting as water retention, night-time moxibustion on Yongquan (KI1) may also draw fire back to its source, promoting sleep and calming the spirit [19].

**4.2.3 Guided Exercises:** Practices such as the 'Two Hands Grasping Feet to Strengthen Kidneys and Waist' posture from the Eight Brocades, the 'Deer Exercise' from the Five Animals Play, and Tai Chi Chuan can guide the flow of qi and blood through specific movements, harmonising yin and yang. Consistent practice in the early morning aligns most effectively with the rising yang energy of heaven and earth, thereby achieving the benefits of strengthening the body and fortifying the kidneys [20].

#### 4.3 Integrating Pattern Differentiation with Rhythm Regulation

Within the holistic framework of Traditional Chinese Medicine pattern differentiation and treatment, rhythm assessment should form a crucial component of diagnosis, with rhythm regulation incorporated into therapeutic protocols.

**For Kidney Yin Deficiency with Excessive Fire, Heart-Kidney Disharmony Pattern:** Manifestations include insomnia with restlessness, dry mouth and night sweats, red tongue with scanty coating, and a fine, rapid pulse. Treatment should focus on nourishing yin, reducing fire, and harmonising heart-kidney function. The formula Huanglian Ajiao Tang combined with Jiaotai Pills, with appropriate modifications, is selected. Concurrently, strict regulation of daily routines is essential, mandating sleep before midnight. This should be supplemented with warm water foot baths in the evening and massage of the Yongquan acupoint to direct fire downward. For spleen-kidney yang deficiency with internal water retention: Symptoms include frequent nocturnal urination, aversion to cold with cold limbs, oedema, and soreness in the lower back and knees. Treatment should focus on warming and tonifying the spleen and kidneys, transforming qi and promoting water metabolism. The formula Zhenwu Decoction combined with Shispi Decoction with modifications is selected. Nursing care should emphasise warmth retention, particularly for the lower limbs and waist.

Patients should be encouraged to engage in moderate daytime activity to warm and invigorate yang qi, while reducing fluid intake in the evening.

#### 5. Conclusion and Outlook

This paper systematically examines the correlation between circadian rhythm disruption and chronic kidney disease, grounded in Traditional Chinese Medicine's theory of 'correspondence between heaven and man'. It indicates that the essence of circadian disruption lies in the desynchronisation between the body's intrinsic rhythms of yin-yang, qi and blood and natural cycles. The core pathogenesis is 'imbalance of yin and yang, with impaired pivotal mechanisms', which subsequently generates pathological products such as dampness, turbid toxins and blood stasis. These damage the kidney collaterals and accelerate CKD progression. For prevention and treatment, an integrated strategy centred on 'aligning with natural rhythms' is proposed. This encompasses multiple levels including lifestyle adjustments and distinctive TCM therapies, reflecting the discipline's strengths in 'preventing disease before it occurs' and holistic regulation. Looking ahead, research in this field may be deepened through the following avenues:

- 1) **Clinical Research:** Design rigorously controlled randomised trials to objectively evaluate the efficacy of 'time-specific traditional Chinese medicine therapies' versus conventional treatments in improving renal function, blood pressure rhythms, and quality of life among CKD patients.
- 2) **Basic Research:** Employ gene knockout animal models to investigate the role of core circadian clock genes in CKD pathogenesis. Examine whether classical kidney-tonifying herbal formulas exert renal protective effects by modulating renal clock genes and their downstream metabolic and fibrotic pathways.
- 3) **Interdisciplinary Research:** Employing wearable devices to dynamically monitor circadian parameters such as body temperature, heart rate, and activity levels in CKD patients. Attempt to establish correlation models linking distinct TCM syndrome patterns with objective circadian rhythm indicators, thereby providing modern, quantifiable reference for TCM pattern differentiation [21].

In summary, deepening the scientific understanding of the 'correspondence between heaven and man' theory and integrating circadian rhythm management into CKD prevention and treatment systems represents a promising direction for achieving complementary advantages between Chinese and Western medicine and advancing CKD prevention and treatment. This warrants further exploration and practical application.

#### References

- [1] Madero M, Levin A, Ahmed S B, et al. Evaluation and Management of Chronic Kidney Disease: Synopsis of the Kidney Disease: Improving Global Outcomes 2024 Clinical Practice Guideline [J]. Ann Intern Med, 2025, 178(5): 705-713.

[2] Juffre A, Gumz M L. Recent advances in understanding the kidney circadian clock mechanism [J]. *Am J Physiol Renal Physiol*, 2024, 326(3): F382-f93.

[3] Qin J, Lu R. Study on TCM Pathogenesis of Perimenopausal Insomnia from Kidney Yang Deficiency [J]. *Liaoning Journal of Traditional Chinese Medicine*, 2020, 47(1): 71-73.

[4] Ren W, Wang Z, Dong Y, et al. Dim blue light at night worsens high-fat diet-induced kidney damage via increasing corticosterone levels and modulating the expression of circadian clock genes [J]. *Ecotoxicol Environ Saf*, 2025, 289: 117636.

[5] Yanshu P D P. Sleep-Wake Rhythm Under the Thought of "Correspondence Between Human and Natural Environment" [J]. *Acta Chinese Medicine*, 2021, 36(11): 2319-2322.

[6] Wang N, Wei R. Research Advances on the Circadian Rhythm of Blood Pressure in Patients with Chronic Kidney Disease and Its Clinical Significance [J]. *Journal Of Clinical Nephrology*, 2014, (3): 185-187.

[7] Jiahuai L X W X C. Research progress in the intervention of circadian clock genes in osteoporosis based on the theory of Yin-Yang fluctuation [J]. *Chinese Journal of Osteoporosis*, 2025, 31(11): 1668-1675.

[8] Chen Y, Guan S, Liu M, et al. 1,3-Dichloro-2-propanol Induced Renal Cell Ferroptosis via the Circadian Clock Protein BMAL1 Targeting GPX4 [J]. *J Agric Food Chem*, 2024, 72(48): 26859-26873.

[9] Fu W J, Huo J L. Targeting circadian rhythm in kidney disease: challenges and prospects [J]. *Int Immunopharmacol*, 2025, 163:115282.

[10] Qiongxiao L L W. Theory and application of yang transforms qi,yin forms form'in Huangdi Neijing [J]. *China Journal of Traditional Chinese Medicine and Pharmacy*, 2025, 40(9): 4399-4405.

[11] Lane J M, Qian J, Mignot E, et al. Genetics of circadian rhythms and sleep in human health and disease [J]. *Nat Rev Genet*, 2023, 24(1): 4-20.

[12] Alex Ferrer, Ariadna Pelegrí, Javier Labad, et al. Clock gene influences on sleep quality and HPA axis in major depressive disorder. [J]. *Sleep medicine*, 2025, 139:108730.

[13] Yi-ke L W-n T B S. Seasonal changes law of melatonin and HPA axis in patients with depression [J]. *China Journal of Traditional Chinese Medicine and Pharmacy*, 2022, 37(5): 2707-2711.

[14] Song Q X, Suadicani S O, Negoro H, et al. Disruption of circadian rhythm as a potential pathogenesis of nocturia [J]. *Nat Rev Urol*, 2025, 22(5): 276-293.

[15] Xiang-hui L Y-j C. Advance for mechanism of circadian rhythm on acute myocardial infarction and its effect on the prognosis of patients [J]. *South China Journal of Cardiovascular Diseases*, 2021, 27(3): 370-373.

[16] Weiwei H J R. Clinical study on correlation between hypertension with liver-kidney yin deficiency and its circadian rhythm with cardio-cerebrovascular diseases [J]. *PRACTICAL ELECTROCARDIOLOGY AND CLINICAL TREATMENT*, 2025, 34(5): 649-653.

[17] Matheus Callak Teixeira Vitorino, Hugo de Luca Corrêa, Verusca Najara de Carvalho Cunha, et al. Clock Gene Expression Modulation by Low- and High-Intensity Exercise Regimens in Aging Mice[J]. *International Journal of Molecular Sciences*, 2025, 26(17):8739-8739.

[18] Li L J X. The Value of Chronotherapy in the Teaching of Traditional Chinese Medicine Based on Li Dongyuan's Theory of Chronotherapy [J]. *Chinese Medicine Modern Distance Education of China*, 2024, 22(11): 34-36.

[19] Yanhong W. Clinical Observation of Acupuncture in Different Time in the Treatment of Heart-kidney Imbalance Type Insomnia [J]. *GUANGMING JOURNAL OF CHINESE MEDICINE*, 2022, 37(3): 481-484.

[20] LI Y, LI H. Modern application of massage theory in Huangdi Neijing [J]. *Chinese Manipulation and Rehabilitation Medicine*, 2018, 9(1): 10-11.

[21] Skarke C, El Jamal N, Genuardi M V, et al. Quantifying Sleep-Wake Rhythms in the Hospital Environment with Digital Technologies [J]. *medRxiv*, 2025,