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Sleep Disruption and Circadian Misalignment in a Rural Himalayan Community of Kangra District, Himachal Pradesh, India

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Abstract: Sleep disruption and circadian misalignment are increasingly recognised as important public health concerns due to their established associations with impaired daytime functioning, metabolic dysregulation, and adverse mental health outcomes. Although these disturbances have been widely investigated in urban and occupational populations, empirical evidence from rural Himalayan settings remains limited. The present community-based cross-sectional study aimed to estimate the prevalence of sleep disruption and circadian misalignment among adults in a rural Himalayan village and to examine their association with lifestyle-related factors, with particular emphasis on evening tea consumption as the principal source of caffeine and pre-sleep electronic device use. The study was conducted among 100 adults (≥18 years) residing in Gamru village, District Kangra, Himachal Pradesh, India, using a structured questionnaire that assessed sleep duration, weekday–weekend variation in sleep timing (social jetlag), electronic device use before bedtime, evening tea intake, and sleep-related disturbances. Descriptive statistics were generated, and associations were examined using chi-square or Fisher's exact tests, with statistical significance set at $p < 0.05$. Circadian misalignment was reported by 69% of participants, while 53% reported daily pre-sleep electronic device use and 60% reported regular evening tea consumption. Although most participants (62%) reported sleeping 7–8 hours per night, a substantial proportion experienced daytime fatigue (60%) and frequent nocturnal awakenings (29%). These findings indicate that sleep disruption and circadian misalignment are highly prevalent even in this rural Himalayan community and suggest that ongoing lifestyle transitions, particularly increased screen exposure and habitual evening tea consumption, may contribute to compromised sleep quality and circadian alignment. Community-level sleep health education focusing on circadian-aligned routines and moderation of evening stimulant intake is therefore warranted.

Keywords: Sleep disruption; Circadian misalignment; Social jetlag; Tea consumption; Sleep–wake cycle; Rural health; Lifestyle factors

I. INTRODUCTION

Sleep is a fundamental biological requirement essential for physiological restoration, cognitive performance, emotional regulation, and metabolic homeostasis. Chronic sleep disruption has been consistently associated with adverse health outcomes, including impaired attention, mood disturbances, cardiometabolic risk, and reduced quality of life [1,2]. Beyond sleep duration, increasing attention is being directed toward sleep timing and regularity, as misalignment between behavioural sleep schedules and endogenous circadian rhythms can independently compromise health [3]. The human circadian system is organised around a central pacemaker in the suprachiasmatic nucleus, which synchronises behavioural and physiological rhythms with the environmental light–dark cycle. Circadian timing is sensitive to behavioural cues such as artificial light exposure at night, irregular sleep schedules, and stimulant intake during the biological evening [3,4]. When behavioural sleep–wake timing deviates from endogenous circadian rhythms, circadian misalignment occurs, commonly manifesting as weekday–weekend sleep variability or "social jetlag" [5].

Modern lifestyle transitions have amplified exposure to factors that disrupt circadian alignment. Evening use of light-emitting electronic devices delays circadian phase by suppressing melatonin secretion and increasing physiological arousal [6]. Similarly, dietary stimulants, particularly caffeine, interfere with sleep initiation and continuity by antagonising adenosine receptors and reducing homeostatic sleep pressure [7]. In rural India, tea is the primary source of dietary caffeine and is commonly consumed in the evening for social, occupational, and cultural reasons; despite its lower caffeine content than coffee, habitual evening intake can adversely affect sleep latency, sleep efficiency, and nocturnal awakenings [7,8]. Tea consumption is seldom specifically examined in rural sleep epidemiology studies, despite its widespread use.

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Rural populations have traditionally been perceived as relatively protected from circadian disruption due to greater exposure to natural light cycles and more structured daily routines [9]. However, increasing digital penetration, changing occupational demands, and evolving social habits suggest that this assumption may no longer hold. Emerging evidence indicates that rural communities are experiencing sleep disturbances comparable to those reported in urban populations [10].

In India, particularly in hilly Himalayan regions, empirical data on sleep health remain scarce. Understanding sleep disruption and circadian misalignment in such settings is essential, as these communities may face unique environmental and behavioural determinants of sleep, along with limited access to specialised healthcare services. The present study therefore aimed to assess sleep patterns, circadian misalignment, and associated lifestyle factors with specific emphasis on evening tea consumption among adults in a rural Himalayan village of Kangra district, Himachal Pradesh.

II. MATERIALS AND METHODS

Study Area

A community-based cross-sectional observational study was conducted to assess sleep patterns, circadian misalignment, and associated lifestyle factors among adults residing in a rural Himalayan setting. The study was carried out in Gamru village, located in Tehsil Dharamshala, District Kangra, Himachal Pradesh, India. The region lies within the mid-Himalayan zone and is characterised by a predominantly rural lifestyle, with livelihoods based on agriculture, homemaking, small-scale business activities, and student populations. Daily routines in the village are influenced by seasonal daylight variation, occupational demands, and increasing penetration of digital technology, making the area suitable for examining sleep disruption and circadian alignment in a rural context.

Study Population and Sample Size

The study population comprised adult residents aged 18 years and above who had been living in the village for at least one year to ensure stable exposure to local environmental and lifestyle conditions. Eligible participants included permanent residents willing to provide informed consent, while individuals reporting acute illness at the time of survey and those with incomplete or duplicate questionnaire responses were excluded. A total of 100 participants were included in the final analysis. In the absence of prior village-level prevalence data on circadian misalignment, a pragmatic sample size was adopted to ensure feasibility while permitting meaningful descriptive and exploratory inferential analyses, which is considered adequate for preliminary community-based epidemiological sleep research.

Sampling Technique and Data Collection Tool

A non-probability convenience sampling method was used, with participants recruited through household visits, community interactions, and local networks, ensuring representation across gender, age groups, and occupations to capture variability in sleep behaviour. Data were collected using a structured, pre-designed questionnaire based on established sleep and circadian rhythm literature, comprising closed-ended items on demographic characteristics, sleep patterns, circadian misalignment, lifestyle factors (pre-sleep electronic device use and evening tea consumption), and sleep-related disturbances. The instrument was reviewed for clarity and cultural relevance prior to administration. Data collection was conducted over one month (January–February 2025) using a mixed-mode approach, with digitally accessible participants completing Google Forms and others interviewed in person. During household interviews, questions were administered in a standardised manner and responses were entered digitally by the investigator to ensure consistency. All responses were screened for completeness, and incomplete or inconsistent entries were excluded from analysis.

Operational Definitions

To ensure consistency and reproducibility, key variables were defined as follows:

- **Sleep duration:** self-reported average nightly sleep time, categorised as <5 h, 5–6 h, 7–8 h, and >8 h.
- **Circadian misalignment (social jetlag):** self-reported noticeable difference in sleep or wake timing between weekdays and weekends. Participants reporting such variation were classified as having circadian misalignment.
- **Pre-sleep electronic device use:** use of mobile phones, televisions, or other electronic screens within **two hours before bedtime**, categorised by frequency.
- **Evening tea consumption:** intake of tea during evening or night hours, treated as the **principal stimulant exposure** in this rural population.
- **Daytime fatigue:** subjective feeling of tiredness or sleepiness during daytime hours, categorised by frequency.
- **Night awakenings:** frequency of waking after sleep onset during the night.
- **Difficulty initiating or maintaining sleep:** subjective difficulty falling asleep or staying asleep.

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Ethical Considerations

The study adhered to ethical principles for human research. Participants were informed about the study purpose, voluntary participation, and their right to withdraw, and verbal informed consent was obtained. Anonymity and confidentiality were maintained, and no personal identifiers were collected. As the survey was non-invasive and minimal risk, formal ethics approval was not required, while ethical standards were strictly followed.

Statistical Analysis

Data were compiled and analysed using IBM SPSS Statistics (Version 26.0) and Microsoft Excel 2019. Categorical variables were summarised as frequencies and percentages and presented in tabular form to describe participant characteristics, sleep patterns, lifestyle factors, and sleep disturbances. Associations between circadian misalignment and selected variables (sleep duration, daytime fatigue, night awakenings, pre-sleep electronic device use, and evening tea consumption), as well as between behavioural exposures and sleep disturbances, were examined using chi-square (χ^2) tests of independence or Fisher's exact test where appropriate. Effect sizes were estimated using odds ratios (ORs) with 95% confidence intervals, and statistical significance was set at $p < 0.05$ (two-tailed).

The primary outcomes of the study were the estimation of the prevalence of sleep disruption and circadian misalignment among participants. The secondary outcomes involved assessing the associations between pre-sleep electronic device use and sleep disturbances, as well as between evening tea consumption and sleep disturbances and daytime fatigue.

III. RESULTS

Sleep Duration and Prevalence of Circadian Misalignment

A total of 100 adult participants were included in the final analysis. Females constituted 56% of the study population, while 44% were males. The majority of participants followed a fixed daily schedule, with only a small proportion reporting irregular or shift-based work.

Sleep duration varied across participants. Most respondents (62%) reported an average nightly sleep duration of 7–8 hours, while 29% reported 5–6 hours, and 7% reported sleeping less than 5 hours (Table 1). Only 2% reported sleeping more than 8 hours per night.

Circadian misalignment, defined as a self-reported difference in sleep–wake timing between weekdays and weekends, was reported by 69% of participants, whereas 31% reported no such variation (Table 1). This finding indicates a high prevalence of social jetlag in the rural study population.

Table 1: Descriptive profile of participants and key sleep-related variables

Variable	Category	n	%
Gender (n = 100)	Male	44	44.0
	Female	56	56.0
Sleep duration	<5 h	7	7.0
	5–6 h	29	29.0
	7–8 h	62	62.0
	>8 h	2	2.0
Circadian misalignment	Yes	69	69.0
	No	31	31.0
Pre-sleep device use	Daily	53	53.0
Evening tea consumption	Everyday	60	60.0

Sleep Disturbances and Daytime Functioning

Despite adequate sleep duration in a substantial proportion of participants, indicators of sleep quality were suboptimal. Daytime fatigue and nocturnal sleep disturbances were frequently reported (Table 2), suggesting compromised sleep efficiency and/or circadian alignment. Daytime fatigue was reported often or sometimes by 60% of respondents. Night awakenings occurred at least once per week in 69% of participants, with 29% reporting awakenings on three or more nights per week. Difficulty initiating or maintaining sleep was reported often or sometimes by 66% of respondents.

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Table 2: Sleep disturbances and daytime functioning among participants

Sleep-related variable	Category	Number of participants (n)	Percentage (%)
Daytime fatigue	Often	20	20.0
	Sometimes	40	40.0
	Rarely	31	31.0
	Never	9	9.0
Night awakenings	Less than once per week	31	31.0
	1–2 times per week	40	40.0
	≥3 times per week	29	29.0
Difficulty initiating or maintaining sleep	Often	28	28.0
	Sometimes	38	38.0
	Rarely	21	21.0
	Never	13	13.0

Association Between Circadian Misalignment and Sleep Disturbances

Associations between circadian misalignment and selected sleep-related outcomes were examined using contingency analyses (Table 3). Circadian misalignment showed a statistically significant association with daytime fatigue (χ^2 test, $p < 0.05$), with affected participants also reporting a higher frequency of night awakenings compared to those without misalignment ($p < 0.05$). However, no statistically significant association was observed between circadian misalignment and gender ($p > 0.05$).

Table 3: Association between circadian misalignment and sleep disturbances

Variable	Category	Circadian misalignment present n (%)	Circadian misalignment absent n (%)	p-value
Daytime fatigue	Often/Sometimes	48 (69.6)	12 (38.7)	<0.05
	Rarely/Never	21 (30.4)	19 (61.3)	
Night awakenings	≥1/week	53 (76.8)	16 (51.6)	<0.05
	<1/week	16 (23.2)	15 (48.4)	
Gender	Male	30 (43.5)	14 (45.2)	>0.05
	Female	39 (56.5)	17 (54.8)	

Statistical test: Chi-square test; Fisher's exact test applied where cell counts were small.

Association Between Lifestyle Factors and Sleep Disturbances

Lifestyle-related exposures, particularly pre-sleep electronic device use and evening tea consumption, were analysed for their association with sleep disturbances (Table 4). Participants reporting daily electronic device use before bedtime were significantly more likely to report difficulty initiating or maintaining sleep ($p < 0.05$). Regular evening tea consumption was significantly associated with both daytime fatigue and frequent night awakenings ($p < 0.05$), indicating that habitual stimulant intake during evening hours may contribute to sleep fragmentation.

Table 4: Association of lifestyle factors with sleep disturbances

Exposure	Outcome	Exposed n (%)	Not exposed n (%)	p-value
Daily pre-sleep device use	Difficulty sleeping (Often/Sometimes)	41 (77.4)	25 (53.2)	<0.05
	Rarely/Never	12 (22.6)	22 (46.8)	
Evening tea consumption (daily)	Daytime fatigue (Often/Sometimes)	42 (70.0)	18 (45.0)	<0.05
	Rarely/Never	18 (30.0)	22 (55.0)	
Evening tea consumption (daily)	Night awakenings ≥1/week	47 (78.3)	22 (55.0)	<0.05
	<1/week	13 (21.7)	18 (45.0)	

Statistical test: Chi-square test (two-tailed).

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Summary of Key Results

- Nearly two-thirds of participants exhibited circadian misalignment.
- Sleep quality was compromised despite adequate sleep duration in many respondents.
- Circadian misalignment was significantly associated with daytime fatigue and night awakenings.
- Daily pre-sleep electronic device use and evening tea consumption were significantly associated with sleep disturbances.
- Gender showed no significant association with circadian misalignment.

IV. DISCUSSION

Overview of Principal Findings

The present community-based cross-sectional study provides empirical evidence that sleep disruption and circadian misalignment are highly prevalent in a rural Himalayan population, despite the absence of widespread shift work or highly industrialised living conditions. Nearly two-thirds of participants (69%) reported weekday–weekend variation in sleep timing, indicative of circadian misalignment or social jetlag. Furthermore, substantial proportions of participants reported daytime fatigue, nocturnal awakenings, and difficulty initiating or maintaining sleep, highlighting compromised sleep quality even among individuals reporting adequate sleep duration.

Importantly, the study identified significant associations between circadian misalignment and sleep disturbances, as well as between modifiable lifestyle factors—pre-sleep electronic device use and evening tea consumption—and adverse sleep outcomes. These findings collectively challenge the assumption that rural lifestyles are inherently protective against circadian disruption and poor sleep health.

Sleep Duration Versus Sleep Quality

Although 62% of participants reported sleeping 7–8 hours per night, subjective indicators of sleep quality and daytime functioning were frequently impaired. This apparent discrepancy underscores the growing recognition that sleep quantity alone is an insufficient indicator of restorative sleep. Fragmented sleep, circadian misalignment, and delayed sleep timing can result in excessive daytime sleepiness and fatigue despite seemingly adequate sleep duration [1,2].

In the present study, more than half of the participants reported frequent daytime fatigue, and nearly one-third experienced nocturnal awakenings on three or more nights per week. These findings are consistent with earlier research demonstrating that misaligned or poor-quality sleep exerts detrimental effects on cognitive performance and metabolic regulation independent of total sleep time [3].

Circadian Misalignment in a Rural Himalayan Context

One of the most notable findings of this study is the high prevalence of circadian misalignment (69%) in a rural Himalayan setting. Social jetlag has been extensively documented in urban populations and industrialised societies [4], but data from rural Indian communities remain limited. The present findings suggest that behavioural and social schedules increasingly override natural circadian cues even in rural environments.

Several factors may contribute to this pattern. Expanding digital connectivity, increased screen exposure during evening hours, and socially driven late bedtimes on weekends may delay circadian phase and disrupt regular sleep–wake timing. Seasonal variation in daylight, common in hilly regions, may further interact with behavioural factors to influence circadian alignment. Similar erosion of the presumed “rural advantage” in sleep timing has been reported in studies from other non-urban settings undergoing lifestyle transitions [5].

Circadian misalignment has been mechanistically linked to impaired glucose tolerance, altered cortisol rhythms, and reduced insulin sensitivity [6,7]. Although metabolic outcomes were not assessed in the present study, the high prevalence of misalignment observed raises concerns regarding the potential long-term cardiometabolic consequences for rural populations.

Role of Pre-Sleep Electronic Device Use

More than half of the participants reported daily use of electronic devices within two hours before bedtime, and this behaviour was significantly associated with difficulty initiating or maintaining sleep. Exposure to blue-enriched light emitted by electronic screens suppresses melatonin secretion, delays circadian phase, and increases physiological arousal, thereby prolonging sleep latency and reducing sleep efficiency [8,9].

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The presence of this association in a rural Himalayan population is noteworthy, as it demonstrates that technology-related circadian disruption is no longer confined to urban or adolescent cohorts. As digital media becomes increasingly integrated into daily life across geographic and socioeconomic boundaries, its impact on sleep health warrants attention in rural health research and intervention planning.

Evening Tea Consumption as a Stimulant Exposure

In contrast to many urban studies that focus on coffee, the present study appropriately examined evening tea consumption, reflecting local dietary practices. Tea is the principal source of dietary caffeine in many rural Indian settings and is often consumed in the evening for social or occupational reasons.

The study demonstrated a significant association between daily evening tea intake and both daytime fatigue and frequent nocturnal awakenings. Although tea generally contains lower caffeine concentrations than coffee, habitual consumption during evening hours can meaningfully interfere with sleep initiation and continuity by antagonising adenosine receptors and reducing homeostatic sleep pressure [10]. Regular tea consumption may therefore contribute to a self-perpetuating cycle of poor sleep and daytime tiredness, particularly when combined with early morning occupational demands.

These findings highlight the importance of context-specific assessment of stimulant exposure in sleep epidemiology. Failure to distinguish between coffee and tea consumption in rural populations may lead to underestimation of caffeine-related sleep disruption.

Daytime Fatigue and Functional Implications

Approximately 60% of participants reported frequent or occasional daytime fatigue. Daytime sleepiness has been linked to impaired attention, reduced work productivity, and increased risk of occupational accidents, particularly in physically demanding rural occupations such as agriculture and manual labour [11].

In resource-limited rural settings, where access to healthcare and occupational safety measures may be constrained, chronic fatigue could have disproportionate socioeconomic and health consequences. The observed association between circadian misalignment, stimulant intake, and fatigue underscores the need for preventive strategies focused on sleep health.

Comparison with Previous Studies

The present findings align with and extend existing literature in several ways:

- Studies from urban and industrialised populations consistently report associations between circadian misalignment and adverse sleep and health outcomes [4,6].
- Earlier work suggested better circadian alignment in rural populations [12]; however, more recent evidence indicates that this advantage may be diminishing as rural lifestyles modernise [5].
- Research from other low- and middle-income rural settings has similarly documented poor sleep quality despite earlier bedtimes and longer sleep duration [13].

By providing data from a rural Himalayan community, the present study contributes novel regional evidence to the evolving understanding of sleep health transitions.

Public Health Implications

Sleep disruption and circadian misalignment represent modifiable risk factors for multiple non-communicable diseases, including obesity, type 2 diabetes, cardiovascular disease, and mood disorders [3,6]. In rural settings, where curative healthcare access may be limited, preventive interventions focused on sleep health could yield substantial benefits.
Community-based strategies may include:

- Sleep hygiene education emphasising consistent sleep schedules
- Reduction of pre-sleep electronic device use
- Moderation of evening tea consumption
- Promotion of awareness regarding the health impacts of circadian misalignment

Such interventions are low-cost, culturally adaptable, and feasible within primary healthcare outreach programmes.

V. CONCLUSION

This community-based cross-sectional study demonstrates that sleep disruption and circadian misalignment are highly prevalent in a rural Himalayan population of Kangra district, Himachal Pradesh. Despite adequate self-reported sleep duration among many participants, a substantial proportion experienced daytime fatigue, frequent nocturnal awakenings, and difficulty initiating or maintaining sleep, indicating compromised sleep quality.

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Nearly two-thirds of participants reported circadian misalignment, highlighting the presence of social jetlag even in a rural setting traditionally presumed to be circadian-protective. Importantly, circadian misalignment was significantly associated with adverse sleep outcomes, and modifiable lifestyle factors, particularly pre-sleep electronic device use and habitual evening tea consumption, were significantly related to sleep disturbances.

These findings suggest that behavioural and technological transitions are reshaping sleep health in rural communities. Addressing sleep disruption and circadian misalignment should therefore be considered an integral component of preventive health strategies in rural India.

VI. LIMITATIONS OF THE STUDY

Certain limitations of the study should be acknowledged when interpreting the findings: its cross-sectional design limits causal inference, reliance on self-reported measures may introduce recall bias, and the modest single-village sample restricts generalisability. Additionally, objective sleep and circadian assessments were not included and should be considered in future studies.

VII. FUTURE SCOPE AND RECOMMENDATIONS

Future research should adopt longitudinal designs to clarify temporal links between circadian misalignment and health outcomes, incorporate objective sleep measures with metabolic and psychological indicators, and evaluate community-based interventions targeting sleep hygiene, reduced evening screen use, and moderated tea consumption. Integrating sleep health education into primary healthcare outreach may provide a cost-effective approach to addressing emerging sleep-related burdens in rural India.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest associated with this study.

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