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Mapping The Evidence On Circadian Disruption And Sleep In Medical Students: A Systematic Scoping Review

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Abstract

Background. Medical training imposes schedules that structurally conflict with biological timing. Literature on sleep in medical students has grown rapidly, yet how much of it measures a circadian dimension remains unclear. Objective. To map the distribution, design and quality of evidence on circadian disruption and sleep in medical students, and to distinguish objective circadian assessment from indirect measures. Methods. A structured PubMed search was run to 23 September 2026. All records were screened using mutually exclusive exclusion categories, with a documented reason for each record. Data were extracted using a 23-variable matrix. Risk of bias was appraised with design-appropriate instruments and reported in each instrument's native output, without composite scores. Circadian assessment was classified as A, A−, B+, B−, B or C. Synthesis was narrative, presented as an evidence map; no meta-analysis was performed. Results. Of 710 records, 626 were excluded at screening and 84 assessed for eligibility; 8 were excluded and 3 reassigned to context, leaving 73 studies plus 2 from other sources, giving 75 studies in the evidence map. Full text was verified for 49 studies; 26 were abstract-only, 4 flagged as having limited information. Designs were predominantly cross-sectional (47 studies). Objective, direct circadian assessment was found in only 3 studies, with a further 3 using partial objective indicators. Risk of bias could be appraised in 55 studies but not in 20. Conclusion. The evidence base rests almost entirely on cross-sectional designs using indirect circadian measures, so mechanistic circadian claims are not yet supported by direct evidence.

Keywords: *Circadian Rhythm, Chronotype, Sleep, Medical Students, Scoping Review*

Abstrak

Latar belakang. Pendidikan kedokteran menempatkan mahasiswa pada jadwal yang secara struktural bertabrakan dengan waktu biologis. Literatur tidur mahasiswa kedokteran berkembang pesat, tetapi belum jelas berapa banyak yang benar-benar mengukur dimensi sirkadian. Tujuan. Memetakan sebaran, desain, dan mutu bukti mengenai disrupsi sirkadian dan tidur pada mahasiswa kedokteran, serta memisahkan bukti yang berlandaskan penilaian sirkadian objektif dari bukti yang berlandaskan ukuran tidak langsung. Metode. Pencarian terstruktur pada PubMed hingga 23 September 2026. Seluruh rekaman diskrining dengan kategori eksklusi yang saling lepas dan alasan yang dicatat untuk setiap rekaman. Ekstraksi memakai matriks 23 variabel. Risiko bias dinilai dengan instrumen yang sesuai desain dan dilaporkan dalam keluaran asli instrumen, tanpa skor gabungan. Penilaian sirkadian diklasifikasikan sebagai A, A−, B+, B−, B, atau C. Sintesis bersifat naratif berbentuk peta bukti; tidak dilakukan meta-analisis. Hasil. Dari 710 rekaman, 626 dikeluarkan pada skrining dan 84 dinilai kelayakannya; 8 dikeluarkan dan 3 dipindahkan ke kategori konteks, menyisakan 73 studi ditambah 2 studi layak dari sumber lain, sehingga 75 studi masuk peta bukti. Teks lengkap terverifikasi untuk 49 studi; 26 studi hanya dari abstrak, empat di antaranya ditandai informasi terbatas. Desain didominasi potong lintang (47 studi). Penilaian sirkadian objektif dan langsung hanya ditemukan pada 3 studi, dengan 3 studi tambahan memakai indikator objektif parsial. Risiko bias dapat dinilai pada 55 studi dan tidak dapat dinilai pada 20 studi. Simpulan. Basis bukti bertumpu hampir seluruhnya pada desain potong lintang dengan ukuran sirkadian tidak langsung, sehingga pernyataan mengenai mekanisme sirkadian pada populasi ini belum ditopang oleh bukti langsung.

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Kata Kunci: Ritme Sirkadian, Kronotipe, Tidur; Mahasiswa Kedokteran, Scoping Review

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I. INTRODUCTION

The circadian system governs almost every physiological process through a central pacemaker in the suprachiasmatic nucleus and a network of peripheral clocks, and misalignment between biological and social time is now understood as a risk pathway in its own right rather than merely an accompaniment of insufficient sleep (Zha et al., 2025). Reviews of shift work show that repeated circadian misalignment is associated with metabolic, cardiovascular and mental health disorders, with risk magnitudes that cannot be fully explained by sleep duration (Boivin et al., 2022). At the cellular level, clock deregulation is accompanied by altered redox signalling and tissue-specific metabolic reprogramming (Konakchieva et al., 2025).

In non-shift populations, evening chronotype and social jetlag are associated with a less favourable cardiometabolic profile, although effect sizes are modest and partly dependent on accompanying behaviours (Zhang et al., 2022). Reviews of social jetlag emphasise that the construct is a proxy for misalignment rather than a measurement of circadian phase, so its interpretation requires caution (Caliandro et al., 2021).

Sleep and circadian rhythmicity are not the same construct. Sleep duration and quality are behavioural outcomes shaped by homeostatic and circadian processes together, whereas circadian phase can only be determined through markers such as dim light melatonin onset (DLMO), 24-hour melatonin or cortisol profiles, core body temperature rhythms, or circadian metrics derived from actigraphy. Chronotype instruments such as the Morningness-Eveningness Questionnaire (MEQ) and the Munich ChronoType Questionnaire (MCTQ) measure self-reported preference and sleep timing, not internal phase. This distinction becomes important once the literature begins to draw mechanistic conclusions from data that are entirely questionnaire-based.

Sleep disturbance in medical students has been documented extensively across countries (Azad et al., 2015), and more recent work links poor sleep quality to the mental health burden in this population (Vidović et al., 2025). What distinguishes medical students from students in general is not workload alone but the temporal structure of their training: rigid early-morning timetables, late-night study blocks before examinations, and, in the clinical phase, the addition of night calls that repeatedly displace sleep timing. This structure resembles shift-work exposure, yet it occurs in an age group whose circadian phase is on average still relatively late.

Existing reviews tend to treat "sleep" and "circadian" as a single exposure group. As a result, an apparently large number of studies can conceal the fact that almost none of them measure circadian phase. No mapping is yet available that systematically separates the evidence according to the type of circadian assessment actually performed, while also reporting transparently which studies could not have their full text verified.

A scoping review with evidence mapping is the appropriate design when the question is "what evidence exists and how sound is its measurement basis" rather than "how large is the effect of an intervention". The heterogeneity of exposures, instruments and outcomes in this literature makes quantitative pooling indefensible; what is needed is an honest map of what has and has not been measured.

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II. METHODS

This study was designed as a *systematic scoping review* producing an *evidence map*. The research question was structured using the PECO framework, with the population consisting of undergraduate or professional medical students, the exposure comprising circadian disruption and/or sleep-related factors, and outcomes including neurocognitive, academic, mental health, cardiometabolic, hormonal/neuroendocrine, and eating behavior outcomes. Eligible studies included primary observational or experimental studies involving medical students or mixed populations with separable medical student data, reporting at least one relevant circadian or sleep exposure and one outcome within the predefined domains. Studies without separable medical student data, without relevant circadian or sleep exposure, without target outcomes, or that were not primary studies were excluded. No publication-year restriction was applied, while language was restricted through the search strategy to English and Indonesian.

The primary information source was PubMed, accessed through the NCBI E-utilities on September 23, 2026. The search strategy combined Medical Subject Headings (MeSH) and text terms related to medical students with three exposure blocks covering circadian and chronotype terms, sleep deprivation and restriction, and combinations of sleep-related terms with hormonal, metabolic, and eating behavior markers. The search retrieved 710 records. A known-item test involving 14 marker studies identified 11 of the 11 studies expected to be retrieved. Two additional studies from the authors' initial collection were also assessed against the same eligibility criteria.

All records were screened at the title and abstract level using mutually exclusive exclusion categories. Records that passed screening were assessed for eligibility using the full text when legally available or the abstract when full text was unavailable. Data were extracted using a 23-variable matrix covering author, publication year, country, journal, study design, sample size, population characteristics, age, sex, exposure, comparator, sleep and circadian variables, instruments, outcomes, effect estimates, confounders, statistical methods, findings, limitations, extraction source, DOI, and PMID. Variables not reported in the available source were recorded as *not reported* (NR) and were not inferred.

Risk of bias was assessed according to study design using the JBI Analytical Cross-Sectional Studies checklist, JBI Quasi-Experimental Studies checklist, Newcastle-Ottawa Scale, and Risk of Bias 2 (RoB 2), as applicable. Assessments were reported using the native outputs of each instrument without generating composite numerical scores or automatically derived overall categories. Circadian assessment was also classified according to the actual measurement performed in each study as objective/direct assessment, partial objective assessment, experimentally manipulated circadian schedule, time-of-day incorporated into the study design without circadian measurement, indirect circadian measures, or sleep variables without a circadian dimension.

The evidence was synthesized narratively and presented as an *evidence map* across three dimensions: type of circadian assessment, study design, and outcome domain. No meta-analysis was performed because of substantial heterogeneity in exposures, instruments, and outcomes, as well as limited comparability of effect estimates across studies. Studies classified as having limited information available or those for which only abstracts were available were not used for quantitative statements. Reporting followed the PRISMA-ScR guideline, while the study selection process was presented using the PRISMA 2020 flow diagram.

III. RESULTS AND DISCUSSION

1. Result

The PubMed search of 23 September 2026 yielded 710 records. At title and abstract screening, 626 records were excluded in mutually exclusive categories: no target-domain outcome (111), population not medical students (103), no circadian or sleep exposure (72), publication type outside the criteria (29), did

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not meet criteria after manual review (214), global sleep quality only and therefore reassigned to context (66), and not a primary study and therefore used as background (31).

A total of 84 reports were assessed for eligibility. At this stage 8 were excluded — seven because of a mixed population without separable medical student data and one because the full text was unavailable, so eligibility could not be assessed — and 3 were reassigned to the context category under rule E5. This left 73 studies from the main search.

The other-sources pathway contributed 15 reports assessed against the same criteria; 9 were not primary studies, 3 had populations other than medical students, and 1 was reassigned to context, leaving 2 eligible studies. These were Wangsa et al. 2022 (Wangsa et al., 2022) and Belsare et al. 2020 (Belsare et al., 2020), neither of which is indexed in PubMed.

Total studies entering the evidence map: 75. The flow reconciles at every stage: 710 = 626 + 84; 84 = 8 + 3 + 73; 73 + 2 = 75. The full selection flow is shown in Figure 1.

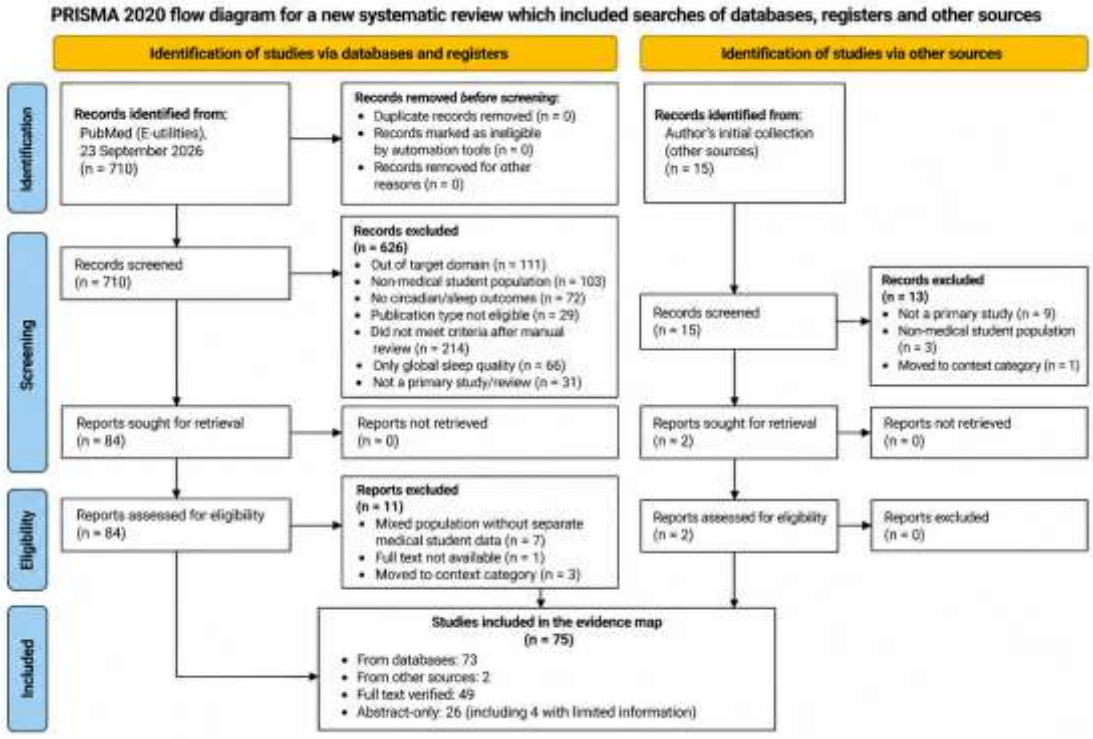


Figure 1. PRISMA 2020 flow diagram of study selection

Full text was verified for 49 studies, whereas 26 studies could be extracted only from the abstract (49 + 26 = 75). Of those 26 abstract-based studies, 4 were flagged *included — limited information available*.

The studies were published between 1981 and 2026, with a median publication year of 2021; 38 studies appeared in 2021 or later and 37 before 2021. This distribution shows that half of the evidence base is more than five years old, and that excluding older publications would remove most of the experimental studies on this map.

The studies originate from 23 countries. The largest contributors are India (16 studies), Saudi Arabia (10), Türkiye (7), Iran (5), the United States (5), China (5), Brazil (4), Germany (4) and Mexico (4); Poland contributed 2 studies and 14 further countries 1 each, including Indonesia (Wangsa et al., 2022). Only two

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studies come from the African continent: one from South Africa (Mhlana et al., 2026) and one from Sudan (Mirghani, 2017). The distribution of study designs is shown in Table 3.

Table 3. Distribution of Study Designs (n = 75)

Design	n
Cross-sectional	47
Longitudinal or repeated-measures observational	15
Experimental / quasi-experimental	8
Randomised controlled trial	2
Other or unspecified observational	3
Total	75

The analysed sample size was reported in 69 studies and not reported in 6. Among studies reporting it, the range was 13 to 1350 participants with a median of 161; 17 studies had fewer than 50 participants and 9 had 500 or more. The total number of participants across studies reporting a sample size is 17,757; this is a simple sum and is not a pooled sample size, because populations, exposures and outcomes are not comparable. Where a study reported the number recruited and the number analysed separately, the number analysed was used.

The distribution of outcome domains is shown in Table 4. Outcome domains were assigned manually for each study by reading the outcomes as reported in the source (Methods 2.7a); the complete classification with a per-study evidence phrase is provided in the supplementary material.

Table 4. Distribution Of Outcome Domains After Manual Validation (Categories Not Mutually Exclusive)

Outcome domain	Number of studies
Mental health	32
Cardiometabolic	20
Academic	19
Neurocognitive / psychomotor	14
Sleep as an outcome	10
Hormonal / neuroendocrine	7
Eating behaviour	6
Circadian / physiological rhythm parameters	4
Other	5

These categories are not mutually exclusive: 29 studies have more than one domain, so the count column must not be summed as a study count and its total does exceed 75. Fifty-two classifications were of high confidence, 18 moderate and 5 low; four of the low-confidence classifications are studies flagged *limited information available*.

Table 5. Instruments Used In The Included Studies

Instrument	Number of studies
Chronotype questionnaires (all types)	22
MEQ and its variants (MEQ, rMEQ, MEQ-SA, MEQ-5, Horne-Östberg)	16
MCTQ	3
Chronotype Questionnaire	2
Composite Scale of Morningness	1
Pittsburgh Sleep Quality Index (PSQI)	14

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Epworth Sleepiness Scale (ESS)	5
Insomnia Severity Index (ISI)	3
Sleep diary	4
Actigraphy or wearable	2
Polysomnography	2

By comparison, biological markers are far less frequent: melatonin was measured in 4 studies (one of them as DLMO) and cortisol in 2.

Nineteen studies fall into category C, measuring sleep variables only, with no circadian dimension. This group contains most of the experimental evidence on the map. Sleep deprivation and restriction studies consistently report decrements in psychomotor and attentional performance: reaction time lengthened after 24 hours of deprivation compared with baseline (Dixit and Mittal, 2015), errors increased on letter cancellation and digit vigilance tasks (Dixit et al., 2012), and psychomotor vigilance task performance deteriorated together with shortened sleep during term time compared with vacation (median 5.75 vs 7.33 hours; $p = 0.037$) (Mota Albuquerque et al., 2023).

For physiological outcomes, elevated 24-hour blood pressure was found in 20.2% of 331 students, with male sex, body mass index, smoking and the LF/HF component of heart rate variability persisting in multivariate analysis (Fujikawa et al., 2009). Thyroid hormones differed between poor and good sleepers for FT4 ($p = 0.01$) and TSH ($p = 0.02$), but not FT3 (Nazem et al., 2021). Sleep duration correlated weakly and positively with morning cortisol ($r = 0.23$; $p = 0.02$) in one study of 100 participants (Mhlana et al., 2026); those authors themselves noted that a single morning cortisol sample cannot assess a rhythm.

The four studies flagged *limited information available* belong to this sleep-related group. They report the direction of an association without extractable figures: perceived sleepiness during Ramadan (Margolis and Reed, 2004), post-call cognitive function under two different call schedules ($n = 20$) (Matthews et al., 2006), serum melatonin levels (Shrivastava and Saxena, 2014), and burnout and depression (Wolf and Rosenstock, 2017). All four are used only to show that evidence exists in the relevant cell of the map, not to support any statement about effect size.

Forty-eight studies fall into category B: they use chronotype questionnaires, social jetlag, sleep timing, call schedules or meal timing. This is the largest part of the evidence map (48 of 75 studies). For academic outcomes, the findings are inconsistent. Some studies report an advantage for morning chronotype: a larger proportion of morning types in the "excellent" grade group (49.1% vs 29%; $p = 0.03$) (Manjareeka et al., 2025), and more evening chronotypes among students with a mean grade of C than among those graded excellent ($p < 0.05$) (Mirghani, 2017). Others found no association: chronotype was unrelated to cumulative grade point average after adjustment (Exp(B) = 0.967; 95% CI 0.931–1.004; $p = 0.079$), whereas absenteeism was negatively associated with it (Exp(B) = 0.22; 95% CI 0.053–0.749; $p = 0.017$) (Alblewi and Mirghani, 2025); no chronotype group outperformed the others on theory marks or attendance in another study (Reddy and Nagothu, 2019); and grade point average did not differ between morning and evening chronotypes in the Indonesian study (Wangsa et al., 2022). One study reported that the differentiating factor was not chronotype itself but learning approach, with morning types tending towards deep learning and evening types towards surface learning (Akram et al., 2018).

For mental health outcomes, the direction of association is more consistent although effect sizes are modest. Evening types had higher state and trait anxiety scores (STAI-S 56.09 ± 4.566 and STAI-T 49.09 ± 6.202; ANOVA $F = 31.798$ and $F = 30.294$; $p = 0.001$) and poorer sleep quality (PSQI 8.14 ± 1.670; $F = 43.663$; $p = 0.001$) (Khaira et al., 2025); lower MEQ scores predicted higher PTSD symptoms ($\beta = -0.1389$; 95% CI −0.273 to −0.0048) (Ozturk and Donmezler, 2024); and depressive symptom severity was higher in non-morning chronotypes (Romo-Nava et al., 2016). One study, however, reported the opposite of the common expectation, with morningness as an independent predictor of increasing Beck Depression

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Inventory scores (Mokros et al., 2017), and another found that the total effect of chronotype on suicidal ideation was non-significant after controlling for mindfulness, the pathway running indirectly through anxiety and insomnia (Nowakowska-Domagala et al., 2023).

Among cardiometabolic and eating behaviour studies that report coefficients, the correlations are small. The correlation between night eating score and body mass index was r = 0.146 (p = 0.004), with sleep quality — specifically sleep latency — as the mediator rather than depression or impulsivity (Gica et al., 2026). The correlation between night eating and global PSQI was r = 0.196 (p < 0.001) in one study (Alghasi et al., 2026) and r = 0.301 (p < 0.001) in another (Tekin et al., 2026). The mediating effect of caffeinated beverage consumption on the pathway from late chronotype to body mass index was significant but very small (estimate −0.01; 95% CI −0.02 to −0.01) (Zhang et al., 2018). In the chrononutrition study in Tabuk, 42% of students skipped breakfast and 49.7% ate dinner late, but no correlation was found between grade point average, body mass index, chronotype and the weekday–weekend difference in sleep timing (Mirghani et al., 2019). In the serum melatonin study not indexed in PubMed, no association was found between sleep timing and melatonin levels (Belsare et al., 2020).

For night-call exposure, one study found that the night-call group slept less (p < 0.001) and had a lower concentration index at the post-call evaluation (p < 0.001), while scores did not differ between groups at the beginning and end of the semester (Perez-Olmos and Ibanez-Pinilla, 2014). Sleepiness was higher after a 12-hour night shift than after a day shift in another study (Fowler and Ellis, 2019).

Table 6. The Three Studies With Objective And Direct Circadian Assessment (Category A)

Study	Marker	Notes
Emens & Lewy 2024 (Emens and Lewy, 2024)	Salivary dim light melatonin onset, 4 times over 7 weeks	Alignment computed as the phase angle difference between DLMO and midsleep; n = 25
Qin et al. 2003 (Qin et al., 2003)	24-hour plasma melatonin profile, sampled every 3 hours (8 points)	Together with leptin, glucose and insulin; number of participants not reported

Three objective/direct studies were identified. Emens and Lewy (2024) found that a shorter phase-angle difference, reflecting later DLMO relative to midsleep, was associated with worse mood ($F_{1,75} = 10.95$; p = 0.001). Qin et al. (2003) reported blunted 03:00 melatonin and leptin peaks in the nocturnal group, with glucose remaining elevated after midnight. Tafoya et al. (2019) found that a history of depressive episodes and low resilience were associated with poorer circadian health based on motor activity and temperature rhythms (n = 15).

Three studies provided partial objective indicators (A−). Benoit et al. (1981) assessed axillary temperature and heart rate every 4 hours using cosinor analysis, but measurements did not cover 24 hours and axillary temperature is not core temperature. Ucar et al. (2018) assessed the cortisol awakening response and heart rate variability, reflecting HPA reactivity rather than circadian phase. Von Gall et al. (2023) used 90-day Fitbit actigraphy to assess workday versus free-day sleep timing without direct circadian rhythm metrics. One study (B+) experimentally manipulated the circadian schedule through a 12-hour shift over 11 days with controlled light and meal times, but without actigraphy or a phase marker to biologically verify misalignment (Niroumand Sarvandani et al., 2025). One study (B−) incorporated time of day by comparing testing at midnight with a rested condition but did not include a circadian measure (Bereuter et al., 2026).

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Table 7. Distribution of Circadian Assessment Categories (n = 75)

Category	n	Proportion of 75
A — objective/direct	3	4.0%
A− — partial objective	3	4.0%
B+ — schedule manipulated without a phase marker	1	1.3%
B− — time of day in the design without circadian measurement	1	1.3%
B — indirect circadian measures	48	64.0%
C — sleep variables only	19	25.3%
Total	**75**	**100%**

When objective evidence is under discussion, the headline figure is 3. When objective and partial objective evidence are discussed together, the two must be stated separately: 3 studies with objective/direct assessment and 3 further studies with partial indicators.

Risk of bias was appraised in 55 of 75 studies; 20 could not be assessed because full texts were unavailable, so item-level appraisal was not possible from abstracts alone. Among the 55 appraised studies, 36 used the JBI Analytical Cross-Sectional tool, 11 the Newcastle-Ottawa Scale (NOS), 6 the JBI Quasi-Experimental tool, and 2 RoB 2. Of the 42 JBI-appraised studies, 16 were classified as *Include* and 26 as *Seek further information*, with recurring concerns regarding unvalidated exposure measures, inadequate confounder adjustment, and self-reported outcomes (Belsare et al., 2020; Khaira et al., 2025; Valliammai et al., 2026). Among 11 NOS-appraised studies, scores ranged from 4/9 to 8/9 stars, with most losses occurring in selection (10/11), comparability (8/11), and outcome (6/11) domains. The two RCTs assessed with RoB 2 were rated *Some concerns* and *High*, respectively; the latter involved concerns regarding blinding, data completeness, self-reported outcomes, and inconsistent statistical reporting (Niroumand Sarvandani et al., 2025). No composite risk-of-bias score or unsupported low/moderate/high classification was assigned.

The evidence map identified six major gaps: (1) no longitudinal study repeatedly assessed circadian phase across the preclinical-to-clinical transition; (2) objective circadian studies were small, with one not reporting its sample size (Qin et al., 2003), and none approached the largest questionnaire study (n = 1,350) (Perotta et al., 2021); (3) cardiometabolic evidence relied mainly on BMI or single markers, with only one study using 24-hour blood pressure monitoring and none extending beyond one academic year (Fujikawa et al., 2009); (4) only two RCTs were identified, both examining short-term sleep or schedule manipulations, with no trial testing class start times or call-schedule changes; (5) despite representation from 23 countries, evidence was concentrated in South Asia and the Middle East, with only two African studies and one from Indonesia (Wangsa et al., 2022); and (6) 26 studies were available only as abstracts and 20 could not undergo risk-of-bias appraisal, limiting verification and interpretation of the evidence.

2. Discussion

The direction of findings was most consistent in two areas. First, sleep deprivation and restriction were repeatedly associated with decrements in psychomotor and attentional performance, including in experimental studies using objective outcomes (Dixit and Mittal, 2015; Dixit et al., 2012; Mota Albuquerque et al., 2023). Second, evening chronotype was generally associated with poorer mental health indicators across several questionnaire-based studies (Khaira et al., 2025; Ozturk and Donmezler, 2024; Romo-Nava et al., 2016). However, consistency in direction does not necessarily indicate strong evidence. Associations between evening chronotype and mental health were generally modest, relied largely on self-reported exposures and outcomes, and often lacked adequate adjustment for confounding. Findings were also not entirely consistent, including evidence that morningness independently predicted increasing depression scores (Mokros et al., 2017) and null findings for academic outcomes (Alblewi and Mirghani, 2025; Reddy and Nagothu, 2019; Wangsa et al., 2022). Overall, these findings suggest that relationships between

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chronotype, mental health, and academic outcomes may be context-dependent rather than robust across populations.

Importantly, the relationships identified in this evidence map should be interpreted as associations rather than causal effects. Only two randomized controlled trials and eight experimental or quasi-experimental studies had designs capable, in principle, of supporting stronger causal inference, and these studies primarily examined short-term sleep or schedule manipulations with relatively small samples. Therefore, the current evidence remains insufficient to establish whether circadian characteristics directly cause differences in academic, psychological, or physiological outcomes among medical students.

A central finding of this review is the substantial difference between direct circadian assessment and indirect measures. The three category A studies measured circadian physiology directly through melatonin timing, 24-hour hormone profiles, or ambulatory activity and temperature rhythms (Emens and Lewy, 2024; Qin et al., 2003; Tafoya et al., 2019). Although these studies reported associations with mood, metabolic profiles, or psychological vulnerability, their samples were small, with 25 participants, an unreported sample, and 15 participants, respectively. The three category A− studies provide useful but incomplete objective information. For example, the cortisol awakening response reflects HPA-axis reactivity rather than circadian phase, consumer actigraphy provides sleep-timing information without direct circadian phase metrics, and axillary temperature measured over less than 24 hours does not provide a complete assessment of core temperature rhythms (Ucar et al., 2018; von Gall et al., 2023; Benoit et al., 1981). These distinctions are important because combining partial objective indicators with direct circadian measures would overstate the strength of the objective evidence.

The category B+ and B− studies further illustrate the limitations of indirect assessment. The B+ study experimentally manipulated a 12-hour schedule over 11 days with controlled light and meal timing but did not use actigraphy or a phase marker to verify biological misalignment (Niroumand Sarvandani et al., 2025). Similarly, the B− study incorporated time of day into its design without measuring a circadian outcome (Bereuter et al., 2026). Thus, although circadian terminology appears frequently in the literature, the evidence supporting biological circadian mechanisms in medical students remains based on only a small number of direct measurements, whereas much of the broader literature relies on self-reported chronotype, sleep timing, or related proxies.

The evidence map demonstrated substantial heterogeneity in exposure definitions, measurement instruments, outcomes, and student populations. Exposures ranged from chronotype and social jetlag to night-call schedules, experimental sleep restriction, and meal timing, while instruments included MEQ, rMEQ, MEQ-SA, MCTQ, PSQI, ESS, ISI, actigraphy, polysomnography, and hormonal markers. Outcomes similarly ranged from reaction time and academic performance to mental health, eating behaviour, and 24-hour blood pressure. Differences in cut-offs and grouping methods were also observed, including studies that classified chronotype according to sample-specific percentiles. This heterogeneity limits direct comparison between studies and supports the use of a scoping review and evidence map rather than quantitative meta-analysis.

The findings also indicate that sleep and circadian domains frequently overlap in measurement but should not be considered conceptually interchangeable. In one study, sleep latency rather than psychological factors mediated the association between night eating and body mass index (Gica et al., 2026), while another found that psychological distress was associated with sleep quality and nocturnal heart rate variability but not sleep-timing parameters (Cvejic et al., 2018). Conversely, Genzel et al. (2013) suggested that sleep timing may be more relevant to academic performance than sleep duration or quality. Because few studies simultaneously assessed sleep and circadian physiology using comparable methods, the present evidence map cannot determine whether these relationships primarily reflect sleep-related pathways, circadian mechanisms, or their interaction.

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The findings indicate several priorities for future research. Longitudinal studies using repeated circadian phase markers, such as DLMO or melatonin profiling, are needed to examine changes across the transition from preclinical to clinical education. Objective circadian measures should also be validated against established phase markers, particularly when actigraphy is used to characterize circadian timing. Intervention studies should move beyond short-term sleep manipulations toward controlled evaluations of academic scheduling, including class start times and clinical call schedules. Greater geographical diversity is also needed, particularly from under-represented regions such as Africa and Southeast Asia. In medical education, the current evidence is insufficient to support chronotype-based scheduling policies, although the consistent association between sleep restriction and impaired psychomotor and attentional performance highlights the potential relevance of adequate sleep to clinical safety. Future studies should therefore clearly distinguish sleep exposure from circadian exposure and report the specific assessment methods used.

This review has several limitations. The structured search was conducted primarily in PubMed, and therefore studies indexed only in Scopus, Embase, Web of Science, or regional databases may not have been captured. The search was also restricted to English and Indonesian publications. Full-text availability limited the assessment of some evidence, with 26 studies contributing information only from abstracts and 20 studies unable to undergo risk-of-bias appraisal. Screening and extraction were performed by a single reviewer using predefined rules, rather than independently by two reviewers. In addition, although the circadian classification criteria were defined in advance and applied consistently, the distinction between categories A and A− involves methodological judgement. Consistent with the scoping review design, no outcome-level certainty assessment using GRADE was performed. One study also showed an inconsistency between its abstract and full-text sample size, which was recorded in the extraction matrix (Liaghatdar et al., 2016).

IV. CONCLUSION

Mapping 75 studies of medical students reveals an evidence base that is broad in number but narrow in method. Forty-seven studies used a cross-sectional design, 48 used indirect circadian measures, and 19 measured sleep variables only. Objective/direct circadian assessment was found in only three studies, with three further studies using partial objective indicators that do not meet the criteria for direct assessment. In our judgement, the experimental evidence on sleep restriction and psychomotor performance is the part of this map whose findings align most closely. Conversely, statements about circadian mechanisms in this population are not yet supported by adequate direct evidence, and the relationship between chronotype and academic outcomes remains inconsistent across studies. Risk of bias could be appraised in 55 studies; in 20 no appraisal was possible because the full text was not legally available. That figure is itself a finding: part of the evidence base in this field cannot be fully inspected by anyone without subscription access. The clearest next priority is a longitudinal study with circadian phase markers following students across the preclinical-to-clinical transition.

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