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SLEEP QUALITY (PSQI) AND SUMMATIVE EXAM PERFORMANCE IN MEDICAL STUDENTS

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ABSTRACT

Purpose of the research: This study aimed to review the relationship between sleep quality, as measured by the Pittsburgh Sleep Quality Index (PSQI), and academic performance among medical students, highlighting neurocognitive consequences and effective interventions.
Materials and methods: The review of research literature was conducted through databases such as PubMed, Google Scholar, and Scopus, including studies from 2007 to 2025.
Results: Multiple studies show that poor sleep quality (PSQI >5) is highly prevalent among medical students and often correlates with reduced GPA, impaired memory, and diminished executive function. Acute sleep deprivation before exams significantly worsens performance. However, inconsistent methodologies, self-reported data, and cross-sectional designs limit causal interpretation. Despite this, evidence supports implementing sleep hygiene education, CBT-I, mindfulness training, and institutional changes to promote better sleep and academic outcomes.
Conclusions: A multifaceted approach is needed to improve medical students' sleep. Combining behavioural interventions and structural academic reforms may reduce stress, enhance cognitive performance, and support long-term academic success. Further longitudinal research using objective measures is recommended to strengthen these findings.

KEYWORDS

Sleep Quality, Academic Performance, Sleep Hygiene, Insomnia

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Introduction

Sleep plays a critical role in maintaining cognitive function, emotional regulation, and overall health. Among medical students, sleep quality is often compromised due to academic pressure, irregular schedules, and psychological stress. This population consistently reports higher rates of sleep disturbances compared to non-medical peers. The Pittsburgh Sleep Quality Index (PSQI) is a validated tool widely used to assess subjective sleep quality. A global PSQI score greater than 5 typically indicates poor sleep, which has been associated with impaired memory, attention, and executive function—skills essential for learning and academic success.

Recent literature highlights a concerning correlation between poor PSQI scores and lower academic performance in medical students, particularly in the context of sleep deprivation prior to high-stakes exams. However, findings across studies are inconsistent due to methodological limitations, including reliance on self-reported data and cross-sectional designs. Despite this, growing evidence supports the need for targeted interventions to improve sleep in medical education settings.

This review aims to synthesise current research on PSQI-measured sleep quality in medical students, its impact on neurocognitive performance and academic outcomes, and to explore potential strategies—such as behavioural and structural interventions—to support student well-being and academic success.

PSQI and the Measurement of Sleep Quality

The Pittsburgh Sleep Quality Index (PSQI) is a widely used and validated instrument designed to assess sleep quality and disturbances over a one-month interval in both clinical and research settings. Developed by Buysse et al. in 1989, the PSQI comprises 19 self-rated questions and 5 additional questions rated by a bed partner or roommate (used for clinical information purposes only). The self-rated items are grouped into seven component scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Each component is scored on a 0-3 scale, with higher scores indicating poorer sleep quality. These component scores are then summed to provide a global PSQI score ranging from 0 to 21, where a score greater than 5 indicates poor sleep quality with high sensitivity and specificity [1]. The PSQI has been extensively validated and is recognised for its utility in differentiating good and poor sleepers across various populations [2].

A global score of ≥5 is the most commonly used threshold, indicating poor sleep quality with high sensitivity (89.6%) and specificity (86.5%) in distinguishing between good and poor sleepers [1]. However, some studies and clinical contexts apply a slightly stricter threshold of ≥6 to define poor sleep quality, particularly to improve specificity in specific populations [2, 3].

The Pittsburgh Sleep Quality Index (PSQI) has demonstrated robust psychometric properties, including good validity and reliability, across various populations, including medical students - a group particularly vulnerable to sleep disturbances due to high academic stress and irregular schedules. Several studies have confirmed the utility of the PSQI in this demographic. For instance, a survey by Alotaibi et al. validated the PSQI among Saudi medical students, reporting a Cronbach's alpha of 0.71, indicating acceptable internal consistency [4]. Similarly, in a Pakistani medical student sample, Surani et al. found the PSQI to be both reliable and sensitive for detecting poor sleep quality [5]. Despite some variations in cultural context and academic systems, the PSQI has consistently shown convergent validity when compared with other sleep and psychological measures such as the Epworth Sleepiness Scale and depression or anxiety inventories.

Prevalence of Poor Sleep Among Medical Students

Poor sleep quality is highly prevalent among medical students globally, with significantly higher rates compared to the general population and their non-medical peers. The demanding academic workload, irregular schedules, and psychological stress inherent to medical training contribute to this trend. A systematic review by Azad et al. reported that between 20% to 70% of medical students worldwide experience poor sleep quality, a prevalence notably higher than the estimated 8% to 18% in the general adult population [6, 7]. Regional studies support these findings: in the Middle East, a study conducted in Saudi Arabia found that 76% of medical students had poor sleep quality. In comparison, research in India reported rates as high as 30,6% [8, 9]. Similar trends are observed in Western countries, with U.S.-based studies indicating that around 70% of medical students attain insufficient sleep [10]. Comparative studies also reveal that medical students report poorer sleep quality and shorter sleep duration than their non-medical peers, suggesting that the medical curriculum exerts unique pressures on sleep health [11]. These findings underscore the urgent need for targeted interventions to address sleep disturbances in medical education settings.

Factors Contributing to Poor Sleep in Medical Students

Medical students frequently report both internal and external factors that disrupt their sleep. As for internal factors, stress, anxiety, academic pressure, and perfectionism rank highest during exam periods. A lot of students report insomnia or fatigue directly linked to academic tensions - a study from Pravara Institute of Medical Sciences Loni in India shows that 48% of them. [9]. Scientific research among third-year medicine students from the University of Mississippi School of Medicine in the U.S.A. indicates that clinical levels of depression were found in 23% of the students, and 57% reported high levels of somatic distress [12]. Several surveys indicate that most students identify stress, late-night smartphone use, and on-call duties as primary causes of sleep disruption [13, 14]. Among external factors, irregular schedules, prolonged study hours, on-call responsibilities, electronics/screen exposure, and roommate disturbances are prominent. For example, a Dutch cohort reported that an average screen time of ~7 hours/day increased screen exposure, especially in the evening, is associated with delayed bedtimes and reduced sleep duration [15]. Moreover, students often cite room-sharing environments and nighttime disruptions from roommates as additional external stressors [9].

The interplay of mental health issues (e.g., anxiety, depression) and lifestyle factors (caffeine consumption, heavy social media use, and circadian misalignment) further intensifies sleep problems. High caffeine intake to compensate for sleep deficits disrupts onset and sleep quality, while late-evening social media use and screen-induced blue light exposure suppress melatonin and shift circadian rhythms [10, 15] These lifestyle patterns often coexist, creating a vicious cycle: stress leads to late-night studying, which increases screen exposure and caffeine consumption, which in turn delays sleep onset and exacerbates anxiety the next day - further compromising sleep quality [10, 16]

The Importance of Sleep for Neurocognitive Function and Learning

Sleep is a crucial biological process that directly supports neurocognitive functions, including executive control, working memory, attention, and long-term memory consolidation —all of which are essential for learning and academic success. During non-rapid eye movement (NREM) sleep, particularly slow-wave sleep (SWS), the brain engages in memory reactivation and systems consolidation, transferring newly acquired information from the hippocampus to the neocortex - a process mediated by slow oscillations, sleep spindles, and hippocampal sharp-wave ripples, which proves NREM sleep is responsible for declarative memory integration [17, 18]. In contrast, REM sleep contributes to the consolidation of procedural, emotional, and creative memory, enhancing neural integration and synaptic plasticity through heightened cortical activity and cholinergic tone [19, 20].

Sleep deprivation, both acute and chronic, has profound consequences for cognitive performance. Even a single night of restricted sleep (less than 6 hours) can impair prefrontal cortex-dependent tasks, including attention regulation, problem-solving, and abstract thinking [21]. Chronic poor sleep is associated with increased daytime sleepiness, mental fatigue, slower cognitive processing, and "brain fog", which significantly reduces information retention, decision-making speed, and academic achievement [22, 23]. Functional MRI studies have shown that sleep-deprived individuals exhibit reduced activation in the dorsolateral prefrontal cortex and increased compensatory activity in lower-order brain regions, reflecting a reduction in neural efficiency [24].

Additionally, sleep disruption modifies emotional reactivity and mental health. Poor sleep quality increases risk for anxiety, depression, and impaired emotional regulation, further compromising the learning environment [25]. Lifestyle factors, such as caffeine overuse, excessive social media exposure, and circadian misalignment, exacerbate these effects by delaying sleep onset and disrupting the balance between REM/NREM sleep, ultimately impairing both declarative and procedural learning [26, 27]. Furthermore, insufficient sleep interferes with the glymphatic system, reducing the clearance of neurotoxins such as beta-amyloid and increasing the long-term risk of neurodegeneration [28]. Altogether, the convergence of neurophysiological, psychological, and lifestyle mechanisms emphasizes the foundational role of sleep in supporting memory, cognition, and academic performance.

Empirical Evidence: PSQI Scores and Academic Performance

Grade Point Average (GPA) - a helpful concept in this study - is a standardized, quantitative index that summarizes a student's academic performance over a specified timeframe, typically a semester or an entire educational program. GPA is calculated as the weighted average of grade points earned across completed courses, where each grade is assigned a numerical value (e.g., A = 4.0, B = 3.0) multiplied by the credit value of the course, then divided by total credits attempted. GPA is commonly reported on a 4.0 or 5.0 scale, depending on the institution or country of origin. Research examining associations between PSQI global scores and academic outcomes (e.g., GPA, exam performance) has provided mixed findings.

In a study of 218 Indian undergraduate medical students, researchers observed significantly lower self-rated GPAs with a median of 2.2 in poor sleepers (PSQI >5), which shows that students with proper sleep efficiency received higher grades than students with poor habitual sleep efficiency. The difference was statistically significant ($p < 0.003$) [29]. Similarly, a cross-sectional survey among dental students found a strong negative correlation between PSQI and GPA. PSQI <5 was associated with low GPA, with a mean score of 2.89, and $p \leq 0.05$ was considered significant. Furthermore, the study proved that only 37.3% of undergraduate dental students slept for more than six hours a day [30]. Another study from Saudi Arabia revealed similar results. The mean sleeping score was higher in students with lower GPAs (1.50 - 2.99) than in students with higher GPAs (3.00 - 4.00). This indicates that students with higher GPAs tend to have better sleep quality [31].

Conversely, a study at Saudi medical school reported no significant difference in academic performance between good and poor sleepers ($p > 0.05$), despite a high prevalence of poor sleep quality [32]. Another study originating in Saudi Arabia also showed that poor sleep or stress did not reveal any crucial association with academic performance, although stress and daytime napping were significantly associated with poor sleep quality [4].

Methodological variations - such as sample size, self-reported vs. objective GPA, and

cross-sectional design - may support these contradictory results. For instance, many studies rely on self-reported grades and self-administered PSQI questionnaires, which can inflate the risk of response bias. Interestingly, the standards of studying and the results may differ even within the same country. A study from

Saudi Arabia reported a significant link between a PSQI score of 5 or higher and academic underperformance. At the same time, a different Saudi Arabian cohort found abnormal PSQI scores significantly related to lower academic achievement ($P < 0.05$). Increasingly, scholars call for longitudinal, multi-center research using objective academic data and sleep tracking to clarify these associations. Until then, the evidence remains contradictory: some cohorts show significant academic detriment associated with poor sleep quality, while others find no measurable impact.

Sleep and Summative Exam Outcomes

Emerging research highlights the crucial role of sleep, particularly in the nights leading up to summative assessments, such as written final exams, OSCEs (Objective Structured Clinical Examinations), and licensure tests, in influencing student performance. While chronic poor sleep quality, often measured by the Pittsburgh Sleep Quality Index (PSQI), has been associated with lower academic achievement across semesters, acute sleep deprivation in the 24-48 hours before high-stakes assessments appears to have an even more immediate and detrimental impact. For instance, Falloon et al. (2021) demonstrated that medical students who slept fewer than 6 hours the night before an OSCE had significantly lower scores compared to those who slept 7-8 hours, with performance deficits particularly evident in stations assessing communication and clinical reasoning [33]. Similarly, a study by Lo et al. (2016) found that even partial sleep restriction in the two nights preceding a written exam was associated with reduced memory recall and slower cognitive processing [22]. Meta-analyses demonstrate that total sleep deprivation before learning produces a significant detrimental effect on memory (Hedges' $g \approx 0.62$), while deprivation after learning has a moderate disruptive impact ($g \approx 0.28$) [34].

These findings suggest that sleep loss immediately preceding summative assessments compromises short-term memory encoding and executive function, independent of overall sleep quality as measured by the PSQI. Moreover, studies in U.S. and Saudi cohorts show that students with self-reported sleep deprivation the night before medical licensure exams or finals were more likely to underperform, even when controlling for GPA and academic preparedness [31]. This evidence reinforces the distinction between chronic sleep health and acute pre-exam sleep behaviours, with the latter playing a disproportionately critical role in high-stakes assessment contexts.

Western and Global Perspectives

Medical students worldwide report exceptionally high rates of poor sleep quality.

A comprehensive meta-analysis published in 2020 estimated a pooled prevalence of poor sleep (as defined by the PSQI) of 52.7% among medical students [35]. This rate surpasses what is typically reported among non-medical students and the general adult public [6]. For instance, a global review highlighted that medical trainees consistently experience poorer sleep quality compared to their non-medical peers and the general population, attributing this disparity to multiple factors, including intensive academic demands and limited awareness of healthy sleep practices [6]. These findings highlight a pervasive issue that spans regions, with significant continent-level differences.

The prevalence of poor sleep among medical students has been shown to vary significantly by region, with the highest rates observed in Europe (approximately 65%) and the Americas (approximately 60%), while lower rates have been reported in Asia (approximately 47%) and Oceania (approximately 31%) [35]. These differences likely reflect variations in educational culture and stress. For instance, many Western medical schools (often ranking globally) impose intense workloads and competitive pass/fail environments. High self-expectations and performance pressure in these contexts may lead students to sacrifice sleep to achieve their academic goals. In contrast, some studies in Asia report lower prevalence estimates. For example, one study conducted in China reported that only around 19% of medical students experienced poor sleep, which may reflect cultural differences in self-reporting or variations in the timing of data collection [36]. Several other Asian studies, however, still report substantial sleep disturbances among medical students, with prevalence estimates around 47%, suggesting that no region is exempt from the issue [6, 35, 36].

Moreover, cultural and socioeconomic factors further shape these patterns. For example, a multicenter study conducted in Latin America during the COVID-19 era reported a 62% prevalence of poor sleep among medical students, aligning with meta-analytic findings for the Americas [37]. In the Middle East and Africa, studies are fewer, but available data indicate similarly high stress and sleep disturbance in many countries. Across cultures, common themes emerge, such as heavy curricula, clinical duties and financial or career pressures. In addition, the widespread lack of awareness about sleep health further exacerbates sleep deficits [6]. For instance, research from 2015 on sleep disturbances among medical students noted that medics globally often lack adequate knowledge of sleep and may hold misconceptions about it, which can compound the impact of stressors [6, 35].

In summary, while poor sleep is a global issue in medical education, evidence suggests that Western students appear to be especially burdened. [35] European and American medical students reported the worst sleep quality in pooled analyses. These differences likely stem from the different academic structures and cultural norms, with Western systems emphasising competition and achievement, in contrast to more varied educational approaches elsewhere. Cultural attitudes (such as de-emphasising sleep or lack of napping) and resource availability (e.g., support services) may further modulate these trends. Taken together, the evidence suggests that sleep deprivation among medical trainees is a global phenomenon with regional variation driven by academic and cultural context [35, 36, 38].

Suggested Interventions: Sleep Improvement Strategies

Interventions to improve sleep in medical students span individual education to systemic curriculum changes. Sleep hygiene education, which involves teaching principles such as maintaining regular sleep schedules, limiting caffeine and alcohol, optimising sleep environment, and avoiding screens before bedtime, is a natural first step. In a recent controlled study, students received a brief sleep physiology lecture, which significantly improved students' sleep knowledge, however, did not significantly improve their PSQI scores four months later [39]. This suggests that knowledge alone is insufficient to change behaviour. Consequently, educators should bundle didactic teaching with practical training (e.g. skills for sleep scheduling and stimulus control) and reinforcement over time. Digital tools can help in this regard: for example, mobile apps or online modules offering personalised sleep hygiene and tracking could augment brief lectures, making sleep education more interactive and continuous (though more research is needed to test efficacy).

Beyond education, cognitive–behavioural approaches show promise. Cognitive Behavioural Therapy for Insomnia (CBT-I) is the gold-standard treatment for chronic sleep problems in adults [40]. It targets maladaptive thoughts and behaviours (e.g. worrying about sleep, irregular bedtimes, excessive napping). Although few studies have tested complete CBT-I protocols in healthy students, evidence from clinical populations suggests that even brief CBT-I can yield substantial improvements. For example, one study demonstrated that a single 60–70-minute CBT-I session, combined with self-help materials, led to a significant reduction in insomnia symptoms after one month compared to no treatment [40]. Scaled to medical schools, CBT-I could be delivered in group workshops or via computerised platforms to maximise access. Digital CBT-I programs (telemedicine or app-based) have been shown to be effective in various populations and could be piloted for students [40, 41]. These interventions also teach cognitive restructuring (challenging perfectionistic or anxious thoughts about performance), which may help reduce sleep-interfering anxiety.

Mindfulness and relaxation-based strategies are another facet of sleep improvement strategies. Mindfulness meditation and training non-judgmental awareness can reduce rumination at bedtime. Some medical schools now offer mindfulness courses or peer-led meditation groups. A meta-synthesis indicates that mindfulness training can decrease burnout and stress among trainees, and smaller studies suggest that improved sleep is a collateral benefit [42, 43]. For instance, structured programs (even intensive ones) have been associated with reduced stress and better emotional resilience [42]. Though controlled trials of mindfulness specifically for sleep in students are sparse, clinicians have long observed its potential to calm the mind before sleep [42, 43]. Pilot programs combining sleep hygiene with mindfulness or relaxation exercises (e.g. guided imagery, progressive muscle relaxation) may be feasible in school wellness curricula.

Structural interventions, which modify the learning environment, are crucial and arguably more scalable than individual counselling. Some medical schools have adopted pass/fail grading or early clinical exposure to reduce competition and stress [42]. Similarly, curriculum reforms can include mandated wellness modules (including sleep health) and limit scheduling of high-stakes exams to reduce cramming. Evidence suggests that pass/fail systems improve mood and group cohesion, which in turn supports better sleep by reducing chronic stress [42]. Additional policy changes might include optimising rotation schedules (e.g. minimising overnight calls during clerkships, avoiding early-morning starts after late shifts), and providing on-campus rest spaces or nap pods during overnight duties.

In summary, a multi-pronged intervention strategy is needed. Basic sleep hygiene education should be part of the core curriculum, but it must be reinforced with skills training and behaviour-change support (e.g., apps, CBT-I). Mindfulness and stress management training can help students build resilience and promote relaxation before sleep. Importantly, institutional policies should aim to mitigate academic stressors: pass/fail grading, flexible scheduling, and protected time for sleep and recovery. Finally, schools should ensure access to mental health resources (psychologists, counsellors) since depression and anxiety co-occur with insomnia. Scalable approaches could include online CBT-I or mindfulness programs offered school-wide. Taken together, the literature emphasises that without systemic change, simple lectures will not be sufficient [39]. Effective strategies combine education, cognitive-behavioural training, mindfulness, and curricular reforms to create a culture that values and facilitates adequate sleep.

Methodological Considerations and Limitations of Current Studies

Current research on the sleep quality of medical students is informative, but it has several limitations. First, nearly all studies are cross-sectional surveys (or baseline cohorts), yielding prevalence estimates at a single point in time. This design precludes causal inferences: we cannot be certain whether poor sleep causes academic problems or vice versa, nor can we track how sleep quality changes throughout medical training. Cross-sectional surveys also suffer from seasonal or situational bias. For example, data collected during exam periods may overestimate the prevalence of chronic sleep problems. Second, almost all data rely on self-reports, most commonly the PSQI. While the PSQI is a validated and widely used tool, it remains subjective and can be influenced by mood and perception. For instance, students with depression or anxiety may rate their sleep as worse even with similar objective sleep compared to peers. Indeed, validation studies in college populations have shown PSQI scores correlate with stress, suggesting caution in interpreting absolute values [44]. Without objective measures (such as actigraphy or polysomnography), it is not easy to verify self-reports.

Heterogeneity is another major issue, with substantial variation reported in study designs and PSQI cutoff thresholds across the literature [35]. Some studies used a PSQI global cutoff of ≥5 to define "poor sleep," while others used ≥6, ≥7, or higher. As expected, using a lower cutoff yields a higher prevalence. A comprehensive meta-analysis of students' sleep disturbances confirmed that PSQI cutoff and geographic region significantly influenced prevalence estimates [35]. Meta-regression also found that smaller-sample studies tended to report higher sleep-problem rates, perhaps reflecting publication bias or chance variation. Sample sizes and sampling methods vary widely (from single-class convenience samples to multicenter cohorts). Non-random sampling and moderate response rates in many studies raise concerns about the representativeness of the results.

In addition, most studies focus on overall prevalence and neglect key covariates. Few surveys capture academic stress, mental health diagnoses, or socioeconomic status, all of which likely mediate sleep quality. Notably, factors like academic pressure, grades, and family support are often inconsistently reported [35]. Without these variables, it is hard to parse why some students sleep poorly while others in the same program do not. Finally, the geographical distribution of research is uneven, with a concentration of studies from Asia and a relative scarcity from regions such as Africa and Oceania [6, 35]. This imbalance limits generalizability: medical training and lifestyle in low-income countries or non-Western cultures may produce different sleep patterns that are not yet fully captured.

Several key methodological limitations recur throughout the literature on sleep quality in medical students. Most notably, the dominance of cross-sectional study designs prevents any meaningful analysis of causal relationships or insight into how sleep patterns and academic outcomes evolve. The overwhelming reliance on self-reported measures, particularly the PSQI, also introduces challenges. Although the PSQI is a widely validated instrument, it is subject to bias from psychological factors, such as stress and mood, and may not accurately reflect objective sleep behaviours [44]. Inconsistencies in how poor sleep is defined, particularly due to varying PSQI cutoff scores, along with a wide variation in sampling strategies that include differences in academic year, geographical region, and timing within the academic calendar, significantly contribute to heterogeneity across studies.

Furthermore, many investigations rely on small or convenience samples, which may inflate prevalence estimates and limit the generalizability of findings. Compounding these issues is the frequent omission of standardised data on academic stress, mental health status, or socioeconomic background, all of which are likely to influence both sleep quality and academic performance.

In light of these limitations, it is essential to note that the current prevalence figures should be interpreted with caution. Future studies should strive for methodological rigour: standardised PSQI cutoffs, larger and more representative samples, and ideally objective sleep measures. A move towards longitudinal, cohort-based research would enable the tracking of sleep patterns over time (e.g., before, during, and after rotations or exams) and better link sleep quality to stress factors, well-being and performance.

Research Gaps and Future Directions

Despite growing recognition of sleep problems in medical students, significant gaps remain. First, longitudinal and interventional studies remain limited. Almost all data are cross-sectional snapshots, and we have little information on how individual students' sleep quality evolves throughout medical school or residency. It is important to emphasise that without longitudinal research, we cannot capture changes over time or identify critical periods where intervention may be most effective [35]. Such studies could also reveal, for example, whether sleep quality deteriorates progressively in subsequent years of education or rebounds after initial adjustment. Multi-institutional collaborations would also be valuable. A recent Latin American multicenter study involving 2019 students demonstrated how pooling data across countries can identify common and region-specific factors [37]. Future research should similarly leverage multi-site cohorts to enhance diversity and statistical power, enabling subgroup analyses by culture, gender, or curriculum type.

Second, there is a clear need for interventional trials to determine which sleep improvement strategies are most effective for medical students. The literature lacks randomised controlled trials (RCTs) of interventions like CBT-I, mindfulness training, or scheduling changes in this population. For example, the single RCT of sleep education showed null effects on sleep quality, highlighting the need to test more potent interventions (e.g. multi-session CBT-I programs or digital cognitive apps) [39]. Future trials could compare, for example, guided online CBT-I with usual care practices, or mindfulness with stress management workshops, measuring both sleep outcomes (PSQI, actigraphy) and academic performance and/or mood. Rigorous designs (including wait-list controls or cluster randomisation by school) would strengthen data quality.

Third, objective sleep measures should be used to supplement self-reports. Actigraphy (wrist-worn accelerometry) can quantify sleep duration, latency and fragmentation over days to weeks. Although more resource-intensive, actigraphy studies in medical students would calibrate the extent of undersleeping or variability in work schedules. Combining actigraphy with sleep diaries and PSQI would provide a comprehensive picture. Even using smartphone sleep-tracking apps or smartwatches (widely available to students) could offer passive data on sleep patterns at scale. These objective data would address biases inherent in recall surveys and allow for the calibration of qualitative data, thereby supporting the validation of the PSQI score in this demographic [44].

Fourth, future studies should systematically include academic stress and mental health variables. Several cross-sectional surveys show that depression and anxiety symptoms strongly predict poor sleep, however many studies omit these covariates [37]. Incorporating validated stress and burnout scales, such as the Perceived Stress Scale or the Maslach Burnout Inventory, would help clarify the nature of these interactions by distinguishing whether it is the academic workload itself or the associated anxiety that has a greater impact on sleep quality. Likewise, measuring lifestyle factors (such as caffeine, alcohol, and screen time) and socioeconomic status could refine our understanding. Longitudinal cohort studies could measure these factors repeatedly, testing whether increases in stress or mood symptoms precede sleep deterioration.

In summary, research needs to evolve beyond descriptive surveys. Priorities include conducting longitudinal, multicenter studies that follow cohorts throughout medical training. Additionally, randomized trials of promising interventions, such as CBT-I, mindfulness programs, and schedule reforms, should measure both sleep and academic outcomes. Objective sleep monitoring, using actigraphy or wearable devices, is also important for validating self-reported data. Finally, comprehensive data collection on stress, mental health, curriculum type, and lifestyle factors is essential. Addressing these gaps will enable us to transition from documenting the problem to understanding the mechanisms and testing solutions.

A good example of the potential benefit of higher quality longitudinal data could be to reveal how exam timing or clinical rotations affect students' sleep. A better understanding of these factors could influence policy design and result in improved student behaviours. Ultimately, integrating sleep, stress, and performance metrics will pave the way for evidence-based programs to enhance both student health and learning outcomes [37].

Implications for Medical Educators and Policy Makers

The widespread issue of inadequate sleep among medical students has important implications for medical educators and policymakers. It is essential for institutions to turn these findings into practical strategies that protect student health and ensure the quality of their performance. To begin with, sleep health should be incorporated into medical curricula and wellness programs. Such a strategy could involve mandatory lectures or modules that cover the principles of sleep science and practical sleep hygiene strategies, along with interactive workshops on stress management techniques to help students apply this knowledge in their daily routines. However, evidence from recent studies demonstrates that knowledge alone is insufficient to improve sleep [39]. Education should be paired with actionable skill-building, teaching students how to establish consistent sleep routines, utilise relaxation techniques, and self-monitor their sleep patterns. Sleep hygiene practices and cognitive-behavioural strategies can be shared through seminars or e-learning platforms, but should also be reinforced by mentors and academic staff. Indeed development of the Faculty culture and behaviours is also key: professors and clinical supervisors should be aware of the sleep issue and promote healthy behaviours (e.g. not praising all-nighters), creating a learning environment that values adequate rest.

Second, scheduling and curriculum policies should be re-examined. Many medical schools have found that grading reforms (pass/fail or narrative evaluations) reduce student anxiety, which may indirectly benefit sleep by lowering overall stress [42].

In addition to reducing stressors, educators should proactively teach students how to cope with inevitable pressures. Workshops and curricula can focus on resilience training: teaching cognitive-behavioural strategies (e.g. cognitive reframing), mindfulness/relaxation techniques, and emotional regulation [45, 46]. For example, interactive exercises like "emotional speed-dating", where students briefly role-play sharing frustrations, have helped normalise handling difficult emotions [45]. Structured programs (such as "Active Resilience Training," adapted from military models) have produced lasting gains in stress-management skills. Complementary approaches that build students' confidence (rather than just reducing pressure) are effective [45, 46]. Simulation drills or early hands-on clinical experiences bolster competence and self-efficacy, traits closely tied to resilience. Likewise, mentorship and peer-support initiatives (e.g. facilitated discussion groups or near-peer mentorship) help students share coping strategies and maintain social support [43].

Schools could also review timetables to minimise circadian disruption: for example, avoiding pre-clinical classes before 8 a.m., limiting overnight call-in clerkships, and scheduling high-stakes exams at reasonable intervals so that students do not resort to chronic all-night study [43]. Some programs now incorporate "protected sleep periods" during intensive rotations (analogous to resident duty-hour rules) or provide nap facilities for on-call students [43]. While the evidence is still emerging, small interventions such as delaying morning rounds by an hour or ensuring a minimum rest period between shifts could have a significant impact on alertness and learning. In essence, curriculum planners should treat adequate sleep as a legitimate educational outcome (just as they do clinical competencies).

Beyond scheduling, many daily routines strongly influence sleep quality and daytime alertness. Maintaining a regular sleep-wake schedule and ample light exposure are crucial [47]. Students should also be encouraged to avoid "social jetlag" (marked shifts between weekdays and weekends) and to minimise late-night studying or screen use, which suppresses melatonin and delays sleep [47, 48]. Meal timing and content also matter. Skipping breakfast or heavy late dinners can cause energy crashes or disrupt sleep. In fact, studies show that students who eat a nutritious breakfast perform better on attention and memory tasks in the morning, while late meals or caffeinated/alcoholic drinks near bedtime fragment sleep [49]. Developing consistency in meal timing supports metabolic regulation (e.g. steady blood glucose), preventing the fatigue and mood dips that accompany erratic eating [49].

Physical activity is another key factor: regular moderate exercise boosts daytime alertness and sleep drive, but vigorous workouts just before bed can make it hard to fall asleep [47]. Hydration and diet quality also play a role. For instance, diets rich in whole grains, fruits/vegetables, and lean protein can sustain energy levels, whereas high-sugar or high-fat meals may lead to sleepiness or restlessness [48, 49]. Finally, individual chronotypes should be considered: "night owls" naturally perform better later in the day and often suffer poorer sleep under early-morning schedules [47, 50]. In short, a holistic wellness approach - regular routines, balanced meals (especially not skipping breakfast or overeating at night), sensible exercise, and light management can markedly improve students' sleep and alertness [47, 48, 49, 50].

Third, schools should institute regular monitoring and support. Routine wellness check-ups may include a validated sleep questionnaire (e.g., PSQI) and screening for insomnia or excessive daytime sleepiness. Students identified as being at risk can be referred to counselling or sleep clinics. Some institutions use anonymous surveys to assess student well-being each semester and adding sleep metrics to this surveillance would signal its importance. Moreover, schools can offer accessible resources, such as on-campus sleep medicine referrals, online CBT-I courses, or peer-support groups, to address stress and sleep problems. For example, an online platform could deliver CBT-I modules to struggling students at a minimal cost and with broad reach. Similarly, encouraging peer-led mindfulness or yoga sessions can provide low-barrier tools for relaxation and stress relief.

Finally, policymakers and accreditation bodies should recognise sleep as a component of trainee health. Accreditation standards could encourage or require medical schools to educate about sleep and fatigue (as some already mandate for resident duty hours). Funding agencies and student health services should allocate resources to student sleep health programs. Importantly, any wellness initiative must be thoroughly evaluated to ensure effectiveness. Gathering data on student sleep and fatigue before and after curricular changes offers valuable insights and helps build a solid evidence base. It has been recommended that institutions "promote education on the impact of poor sleep, regular monitoring of sleep and practising sleep hygiene [35]. Similar calls have been made to shift research toward initiatives that improve sleep education and identify students at risk [6]. In summary, medical educators and policy makers must acknowledge sleep as foundational to learning and health. Practical steps include embedding sleep instruction into the curriculum, adjusting schedules to allow for adequate rest, and implementing routine sleep/fatigue screenings. Resources for stress reduction (mindfulness, CBT-I) should be scaled up, and a supportive culture that destigmatises seeking help must be cultivated. By taking these actions informed by the literature, institutions can help ensure that tomorrow's physicians are not the victims of sleep deprivation [6, 39].

Summary

The Pittsburgh Sleep Quality Index (PSQI) is a validated tool used to assess sleep quality, especially among medical students who often face poor sleep due to academic stress, irregular schedules, and mental health challenges. Studies show a high global prevalence of poor sleep in this group, which may impair memory, cognition, and academic performance. While some research links poor PSQI scores to lower GPA, findings are mixed. Interventions like CBT-I, mindfulness, sleep hygiene education, and curriculum reforms (e.g., pass/fail grading) show promise. Experts call for longitudinal studies, objective sleep tracking, and systemic changes in medical education to address this widespread issue.

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