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A comparative analysis of partial sleep restriction versus split sleep regimen on cognitive processing, declarative memory, and affective behaviour in nursing students

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ABSTRACT

Objectives: Sleep plays a regulatory role in functions such as abstraction, fluid intelligence, and declarative memory. This research seeks to assess the influence of two sleep restriction schedules—partial nocturnal sleep restriction and a split sleep (SS) regimen—on fluid intelligence and various memory functions (including encoding, consolidation, and retrieval) in shift-working nurses.

Materials and Methods: The research involved 46 4th-year nursing students (23 males and 23 females) assigned to night duties, categorised into two groups: Partial sleep restriction (5 h of night sleep with 4 h of daytime recovery sleep) and SS (5 h of night sleep with 1.5 h of an afternoon nap and recovery sleep of 2.5 h following the tests). Instruments such as the Pittsburgh sleep quality index (PSQI), Karolinska sleepiness scale (KSS), and Raven's Progressive Matrices were utilised to evaluate sleep quality, sleepiness levels, overall mood, benefits of daytime naps, and fluid intelligence. Memory-related activities comprised a picture-encoding task and a factual knowledge task, evaluated through subjective assessments and two alternative choice questions.

Results: The PSQI global scores highlighted notable differences, with female nursing students in the partial sleep group scoring lower (9 ± 2.311) than their counterparts in the SS group (5 ± 1.09). Sleepiness, gauged by the KSSKSS score, was higher in the partial sleep group (7 ± 3.2) compared to female nursing students in the SS regimen (5 ± 5.8). Results from Raven's progressive matrices pointed to delayed abstraction in the partial sleep restriction group (9.31 ± 6.24) in contrast to the SS group (9.01 ± 5.59), indicating poorer performance in visual attentive tasks. Positive and negative affect schedule scores unveiled heightened negativity in mood due to sleep restriction in the partial sleep group, with less hostility observed in those with an afternoon nap, albeit not reaching statistical significance. Positive moods exhibited fluctuation, with attentiveness declining in the partial sleep group. The study affirmed the advantages of a daytime nap on long-term memory. Female nurses in the SS regimen displayed statistically significant picture encoding accuracy (78 ± 3.65) with faster reaction times (2 ± 6.37) compared to the partial sleep group. Males in the SS regimen recorded a higher percentage of hits (88 ± 5.16). Learning sessions at 3 pm, coinciding with the circadian dip, affected the partial sleep groups, whereas the nap mitigated such effects for the SS group. Allowing a 1.5-h afternoon nap synchronised with the circadian dip enhanced memory in the SS group.

Conclusion: By comparing partial nocturnal sleep restriction and a SS regimen, this study unveils their distinct effects on fluid intelligence and memory processes among shift-working nurses. The results provide valuable insights into the degree of dependence of basic cortical functions on sleep for healthcare professionals navigating demanding schedules, underscoring the significance of accounting for both nocturnal sleep duration and daytime naps to optimise cognitive performance.

Keywords: Consolidation, Memory encoding, Memory retrieval, Sleep deprived, Split sleep

INTRODUCTION

Sleep plays a crucial role in memory functions, contributing both to the stabilisation and integration of memories for long-term storage after learning,[1] and in preparing the brain to encode new information before the learning process.[2] However, nurses working night shifts often face challenges, experiencing compromised sleep quality due to extended working hours and shift work.[3,4] This sleep disruption, a consequence of the demanding nature of nursing professions involving high levels of physical and mental activity, has broader implications, as chronic sleep restriction is linked to poorer academic performance and a reduced capacity to encode new information.[4-7]

The healthcare industry, requiring 24/7 patient care, mandates clinical workers to engage in rotating schedules, shifting between day, evening, night, and early morning shifts.[8] This demanding schedule poses a significant challenge for learning and memory, especially considering the restricted sleep that adolescents currently obtain. Addressing this challenge is crucial, and daytime naps have emerged as a potential solution. Laboratory studies consistently show that naps enhance memory in both children[9-11] and adults.[12-14] While traditionally viewed as compensatory measures for inadequate nocturnal sleep, an alternative perspective suggests incorporating naps into daily schedules as a beneficial practice for everyone.[15]

Despite the National Sleep Foundation offering broad sleep duration guidelines, there is little consensus on the specific durations considered sufficient for most individuals.[16] Memory formation is vital for an organism's strategic adaptation to environmental changes, occurring through encoding, consolidation, and retrieval. The relationship between sleep and memory has been a focus of research for decades, experiencing a renaissance in the last three decades.

Observations indicating the positive impact of sleep on memory date back to the early days of experimental memory research. Sleep deprivation studies, evaluating performance in specific working situations and measuring task performance in healthy subjects, emphasise the critical role of sleep on cognitive functions.[17] Continuous sleep deprivation for 37 h has been associated with more pronounced decrements in performance, especially in tasks of interest.[18] Recent meta-analyses confirm that sleep deprivation adversely affects accuracy and response time during working memory tasks.[19]

The essential cognitive capacities for survival, including acquiring, consolidating, and retrieving information, collectively referred to as learning and memory, are significantly influenced by sleep. Sleep deprivation induces a wide range of negative effects on cognitive functions,[20,21] with memory and mood states being particularly affected.[22] Experimental research on the consequences of sleep loss has predominantly focused on total sleep deprivation after a night, revealing its detrimental impact on various cognitive functions. However, understanding how memory is affected when learning occurs under a split sleep (SS) schedule remains an unexplored area.

Objectives of the study

Primary objective

To compare the influence of two sleep restriction regimens, that is, – partial nocturnal sleep restriction and a SS regimen, on fluid intelligence and memory encoding, consolidation, and retrieval among shift-working nurses.

Secondary objective

A comparative assessment of overall mood and the effect of daytime naps on the above-mentioned cortical functions.

MATERIALS AND METHODS

Source of data

IV year nursing students posted on night duties (8 pm–8 am) at Karnataka Lingayat Education Society's (KLES) Prabhakar Kore Hospital and Medical Research Centre (MRC), Belagavi.

This study has received approval from the Institutional Ethics Committee according to the letter number MDC/JNMCIEC/376 from IEC Karnataka Lingayat Education Academy of Higher Education and Research, Jawaharlal Nehru Medical College, Belagavi, obtaining voluntary written informed consent from all participants and explaining the entire study protocol before the study.

Study design

This was a Comparative study.

Study period

The study period was 6 months.

Sample size

The sample size for the study was calculated by considering the expected difference in outcomes between the two groups: the partial nocturnal sleep restriction group and the split sleep regimen group. The calculation incorporated the means and standard deviations from both groups (Mean = 2.86, SD = 0.33 for group 1, and Mean = 2.48, SD = 0.32 for group 2), the level of significance (95%, corresponding to a Z-value of 1.96), and the power of the test (95%, corresponding to a Z-value of 1.64). Additionally, a 10% attrition rate was included in the calculation. Based on these parameters, the required sample size was determined to be 23 participants per group, resulting in a total of 46 participants for the study.

Study venue

Research laboratory at the Department of Physiology.

Comparative groups

Partial nocturnal sleep restriction group

Nurses posted for night duties to KLE's Prabhakar Kore Hospital and MRC are allowed to sleep for 5 h during the night duties and next daytime recovery sleep of 4 h.

Split Sleep (SS) group

Nurses posted for night duties to KLE's Prabhakar Kore Hospital and MRC are allowed to sleep for 5 h during the night and next day an afternoon nap of 1.5 h followed by a battery of tests and a recovery sleep of 2.5 h following it Figure 1.

Inclusion criteria

The inclusion criteria were- 1) IV year nursing students posted on night duties (8pm-8 am) at KLE's Prabhakar Kore Hospital and MRC, 2) Both genders, and 3) Body mass index not >30.

Exclusion criteria

The following criteria were excluded from the study- 1) Smoker, 2) Diagnosed with any psychiatric condition, 3) Participants who have traveled across >2 time zones 1 month before the study, and 3) Participants who consume ≥5 caffeinated beverages per day.

Tools

Pittsburgh sleep quality index (PSQI)

The PSQI is a self-administered questionnaire designed to evaluate sleep quality and disturbances over a 1-month period. It comprises nineteen individual items that generate seven 'component' scores, assessing subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The sum of scores for these components yields a global score. Each of the seven component scores ranges from 0 (indicating no difficulty) to 3 (indicating severe difficulty), and when summed, they produce a global score ranging from 0 to 21. Higher scores on the PSQI indicate poorer sleep quality.

Karolinska sleepiness scale (KSS)

The KSS measures subjective sleepiness levels at a specific time during the day. It employs a nine-point

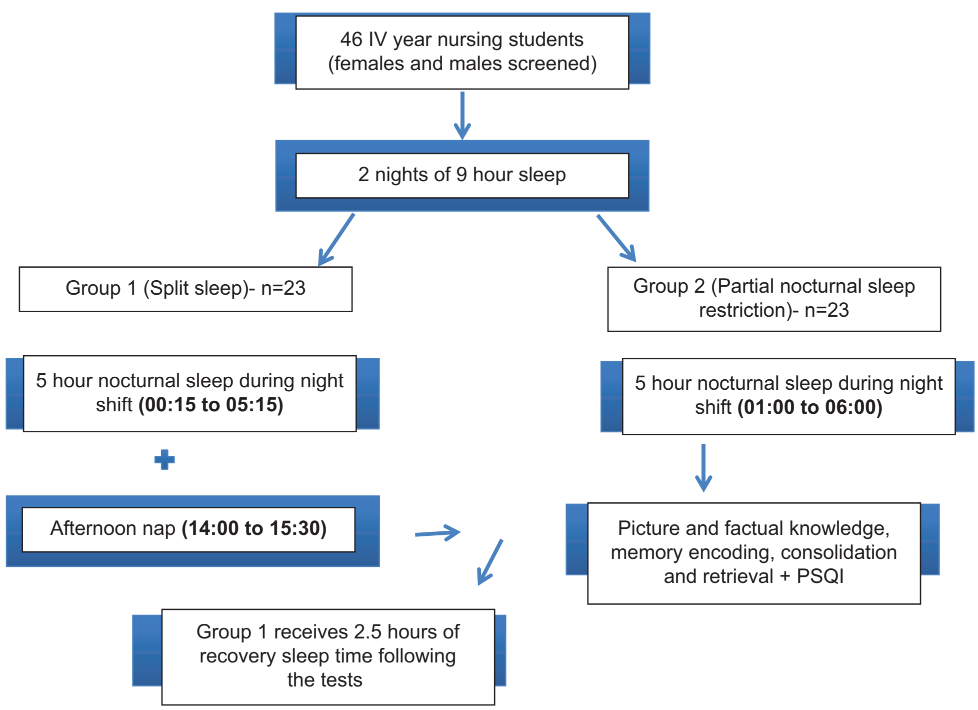

Figure 1: Flow chart depicting the experimental procedure for both the split sleep group ($n = 23$) and the partial nocturnal sleep restriction group ($n = 23$). PSQI: Pittsburgh sleep quality index.

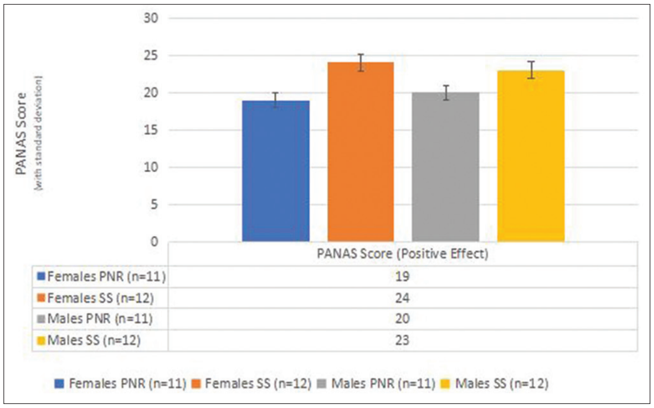

Figure 2: Comparison of positive and negative affect schedule (positive affect) scale among partial nocturnal restriction (PNR) and split sleep (SS) regimens among shift workers. ± represents standard deviation.

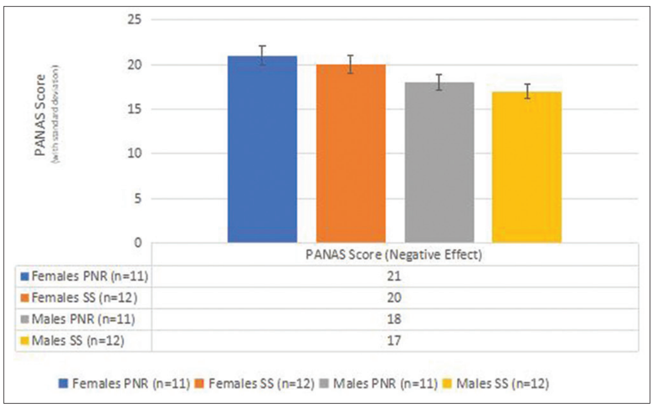

Figure 3: Comparison of positive and negative affect schedule (negative affect) scale among partial nocturnal restriction (PNR) and split sleep (SS) regimens among shift workers. ± represents standard deviation.

scale, where subjects indicate the level that best reflects their psycho-physical state in the last 10 min. Scores range from 1 (extremely alert) to 9 (extremely sleepy, fighting sleep).

Raven's progressive matrices (RPM)

RPM is a non-verbal test commonly used to assess general human intelligence and abstract reasoning, serving as a non-verbal estimation of fluid intelligence. The task involves identifying the missing element in a pattern, typically presented in matrix form, hence the name Raven's Matrices.

Memory tasks

Picture encoding task

Participants viewed 60 images depicting various landscapes and

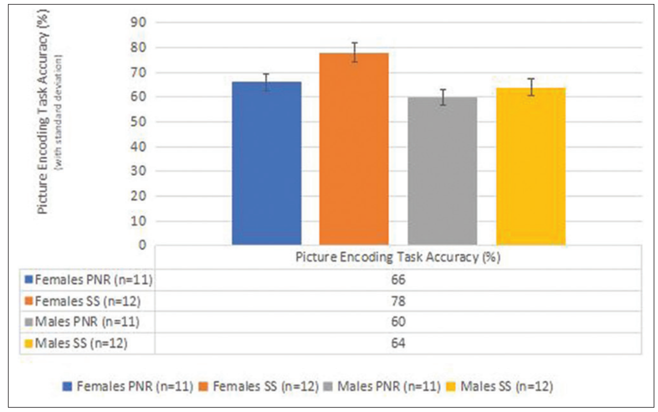

Figure 4: Comparison of picture encoding task accuracy among partial nocturnal restriction (PNR) and split sleep (SS) regimens among shift workers. ± represents standard deviation.

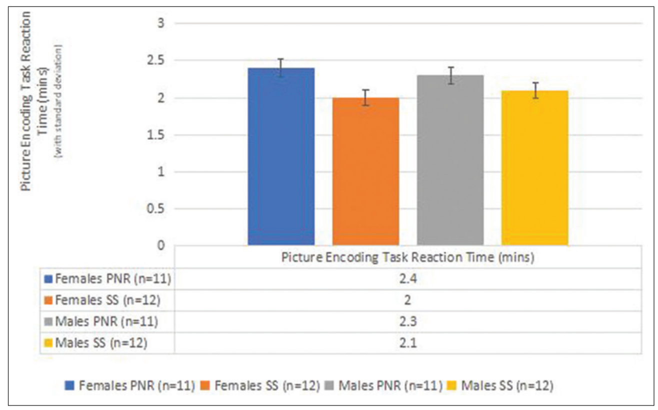

Figure 5: Comparison of picture encoding task reaction times among partial nocturnal restriction (PNR) and split sleep (SS) regimens among shift workers. ± represents standard deviation.

Table 1: Sociodemographic details. In total, 46 participants whose average age was 22 years were taken for this study.

Variables	
Age	21–23 years
Gender	• Females (SS=12, PNR=11) • Males (SS=12, PNR=11)
BMI	20±5.11 kg/m^2
Caffeine consumption	Nil

SS: Split sleep, PNR: Partial nocturnal restriction, BMI: Body mass index

building types, with half featuring buildings and the other half without. These images were divided into three sets of 20 (10 buildings, 10 without), with two sets presented during both encoding and retrieval (40 old images) and one set presented only during retrieval (20 new images). Encoding occurred in a single 15-min block, during which participants were instructed

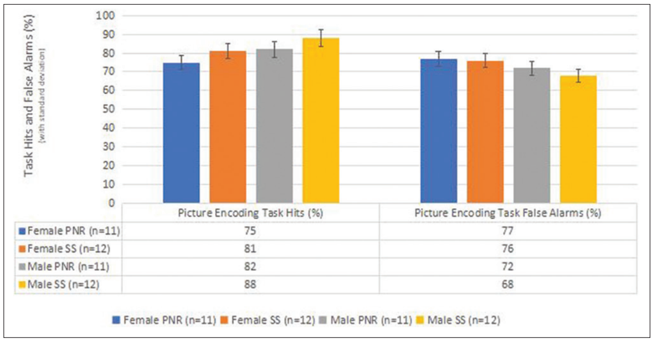

Figure 6: Comparison of picture encoding task hits and false alarms among partial nocturnal restriction (PNR) and split sleep (SS) regimens among shift workers. ± represents standard deviation.

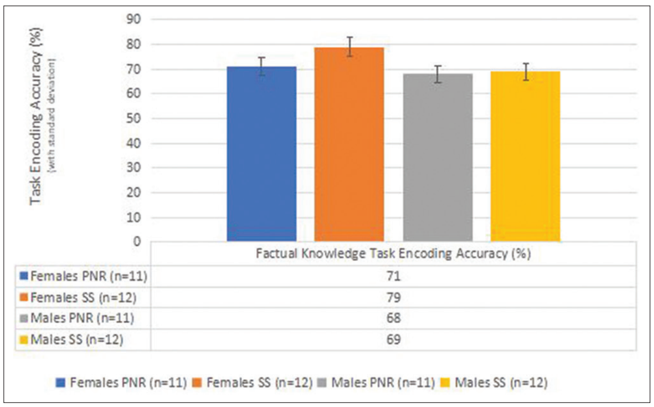

Figure 7: Comparison of factual knowledge task encoding accuracy, among partial nocturnal restriction (PNR) and split sleep (SS) regimens among Shift workers. ± represents standard deviation.

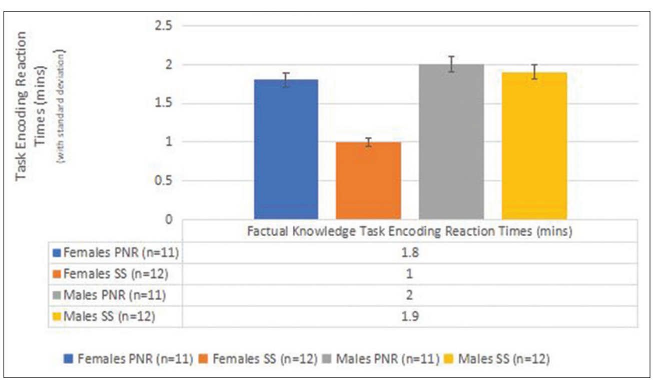

Figure 8: Comparison of factual knowledge task encoding reaction times, among partial nocturnal restriction (PNR) and split sleep (SS) regimens among shift workers. ± represents standarddeviation.

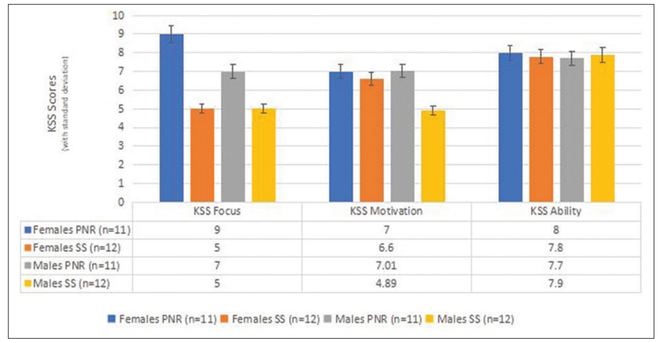

Figure 9: Comparison of Karolinska Sleepiness Scale (focus, motivation and ability) scores during factual knowledge task- encoding among partial nocturnal restriction (PNR) and split sleep (SS) regimens among shift workers. ± represents standard deviation.

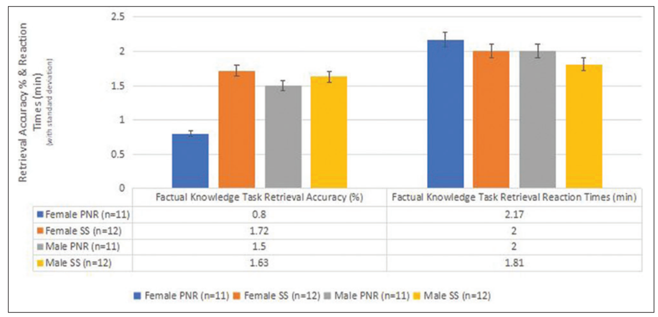

Figure 10: Comparison of factual knowledge task- retrieval accuracy and reaction times, among partial nocturnal restriction (PNR) and split sleep (SS) regimens among shift workers. ± represents standard deviation.

to carefully observe each image without prior notification of a memory test. Following a 2-min presentation of each image, participants indicated whether it featured a building or not. Retrieval involved recognising 40 old images randomly mixed with 20 new images, with participants rating their confidence on a five-point scale '(1) definitely did not see, (2) probably did not see, (3) Unsure, (4) probably saw, (5) definitely saw.' Confidence ratings of 4 or 5 to old images were classified as 'hits,' while the same ratings for new images were considered 'false alarms.'

Factual knowledge task—encoding

Participants were informed that all learned information would be tested. They underwent two 30-min blocks of learning in the morning, each focusing on a different animal type, with a break in between. The learning materials consisted of approximately 10 slides of information and images for each animal type. After each block, participants rated their subjective focus, motivation, and ability to learn on a 7-point scale, with scores inverted for analysis.

Factual knowledge task—retrieval

This task involved answering two alternative choice questions followed by a confidence rating. Participants answered 40 questions (10 for each animal type) related to materials learned in the morning and afternoon, with memory performance assessed by correct responses, including trials where no certainty response was recorded.

Experimental protocol

The participants were divided into one of two groups: Partial sleep (*n* = 23) and SS (*n* = 23) [Table 1].

The research commenced with two initial nights of 9 h of sleep during the night before the participants began their night shifts. On the 3rd day, which marked the onset of their night shifts, one group was allocated a 5-h window for nocturnal sleep (from 01:00 to 06:00), while the other group also had a 5-h opportunity (from 00:15 to 05:15) along with a 1.5-h nap in the afternoon (from 14:00 to 15:30) on the following day. Compliance with the time durations was monitored by phone calls to the participants as well as to their roommates. The next day, at a stipulated time, data collection would take place at their hostels. The group subjected to partial sleep restriction undertook learning tasks involving picture and factual knowledge in the morning after returning to their accommodations, whereas the group following the SS schedule engaged in these tasks in the afternoon of the subsequent day. Subsequently, memory encoding, consolidation, and retrieval activities were carried out. All sleep duration and experiences were ascertained via the door-to-door data collection and the PSQI questionnaire.

Statistical analysis

Data analysis was done using the Statistical Package for the Social Science 26.0 version. The data sample was normally distributed. The data was analysed as mean ± standard deviation. The Independent Student's *t*-test was used to quantify the differences between sleep architecture, picture, factual encoding, and retrieval metrics.

RESULTS

The study revealed distinct effects of varying sleep patterns on female nursing students' sleep quality, where those in the partial nocturnal sleep restriction group exhibited significantly poorer sleep quality (9 ± 2.311) compared to their counterparts in the SS group (5 ± 1.09). Sleepiness, assessed through the KSS score, indicated a heightened propensity for sleepiness (7 ± 3.2) in the partial sleep restriction group compared to females in the SS regimen (5 ± 5.8), underscoring gender-specific differences. The partial sleep restriction group displayed delayed abstraction (9.31 ± 6.24) in Raven's Progressive Matrices compared to the afternoon nap group (9.01 ± 5.59), indicating impaired performance in visually attentive tasks common in shift-working nurses [Table 2]. Positive and negative affect schedule (PANAS) scores [Figures 2 and 3] reflected increased negativity in mood due to sleep restriction in the partial sleep group, contrasting with less hostility in those with an afternoon nap. In memory tasks, the SS regimen demonstrated significant accuracy in picture encoding (78 ± 3.65) [Figure 4] and faster reaction times [Figures 5 and 6] (2 ± 6.37) for female nurses. Learning sessions at 3 pm affected partial sleep groups, while the nap counteracted these effects for the SS group, indicating enduring memory benefits.

DISCUSSION

We enrolled 46 4th-year nursing students assigned to night duties, dividing them into two groups: One underwent a SS format[23] with 5 h of nocturnal sleep and a 1.5-h mid-afternoon nap, while the other experienced partial nocturnal sleep restriction[24] with only 5 h of sleep. Our objective was to investigate the impact of different sleep restriction patterns on declarative memory. The research aimed to assess the influence of these sleep regimens on overall sleep quality, sleepiness levels, fluid intelligence, abstract reasoning, and declarative memory [Figures 7 and 8] processes such as encoding, consolidation, and retrieval.[25-28]

The PSQI global scores highlighted that females in the partial sleep restriction group exhibited poorer scores compared to their counterparts in the SS group. Although the PSQI global scores among male participants were not statistically significant, there was a trend toward deterioration in the partial sleep-restricted group. Sleepiness, measured by the KSS

Table 2: Comparison of PSQI global score (serial no. 1), KSS (Baseline) (serial no. 2) and Ravens Progressive Matrices (serial no. 3) among partial sleep deprived (PNR) and SS regimens among shift workers.

S. No.	Description	Females PNR (*n*=11)	Females SS (*n*=12)	Males PNR (*n*=11)	Males SS (*n*=12)
1.	PSQI global score	9±2.311	5±1.09	7±5.7	5±4.45
	P-value	0.01*		0.12	
2.	KSS score	7±3.2	5±5.8	5±1.114	4±3.7
	P-value	0.04*		1.112	
3.	Raven's progressive matrices	9.31±6.24	9.01±5.59	8.18±4.37	8.44±4.108
	P-value	0.03*		0.8	

*Statistically significant, *P*<0.05, PSQI: Pittsburgh sleep quality index, KSS: Karolinska sleepiness scale, SS: Split sleep. ±represents standard deviation score [Figure 9], indicated a higher propensity for sleepiness in the partial sleep restriction group compared to females in the SS regimen. Females generally displayed greater sleepiness. These findings align with existing studies suggesting that poor sleep quality is a prevalent issue among nurses globally.[29]

Results from Ravens Progressive Matrices pointed to delayed abstraction in the partial sleep restriction group compared to the group with an afternoon nap, indicating poorer performance in visually attentive tasks. This echoes studies demonstrating that shift-working nurses exhibit diminished performance in visually attentive tasks compared to their off-duty counterparts, affecting their mastery of high-attention tasks.[30]

PANAS scores revealed that sleep restriction led to increased negativity in mood in the partial sleep group, whereas those who had an opportunity for an afternoon nap showed less hostility, although not statistically significant. Positive moods displayed lability, with attentiveness dipping in the partial sleep-restricted group and reaching their lowest point the afternoon of the next day. This suggests that sleep restriction had a deleterious effect on certain moods due to alterations in homeostatic sleep drive and circadian modulation.[31]

Our study supports the idea that a daytime nap benefits long-term memory.[32] According to Cousins *et al.*,[33] 'Naps were also suggested to aid the retention of lecture material in a more applied school setting, where students given a 2 h nap opportunity retained more than those who attended regular classes instead.' Newer research is bringing out that while shorter naps of 30 min or so offer enhanced alertness and memory consolidation and intrude less on our schedules, the beneficial effects of naps of 60 min and above are still much under debate. Especially in the case of chronically sleep-deprived adolescents, as are shift-working nursing students, an adequate nap time may be variable in comparison to an ordinary working individual.

Picture encoding accuracy was statistically significant in female nurses of the SS regimen with faster reaction times compared to the other group. Across genders, males in the SS regimen showed a higher percentage of hits. Learning sessions at 3 pm, corresponding to the circadian dip, revealed that partial sleep groups were impacted by the afternoon dip in performance, while the nap counteracted such effects for SS groups. Allowing a 1.5-h afternoon nap aligned with the circadian dip improved memory in the SS group, supporting the idea that even shorter afternoon naps provide long-lasting memory benefits [Figure 10].[13] The SS regimen promoted better memory encoding and retrieval of declarative memory, aligning with the synaptic homeostasis hypothesis. Although the SS group received less slow-wave sleep, it was distributed effectively; promoting hippocampal-dependent memory processes compared to partial nighttime sleep restriction.

Implications

It is imperative to conduct research that investigates the factors predicting sleep deterioration among nursing faculty, as this is essential for developing effective mitigation strategies that cater to their unique needs and foster sleep health and overall well-being. Future studies should delve into the health implications of sleep quality, or its absence, on cognition. Further, a comparison between nursing students and nurses working in jobs could highlight their psychological differences, which further act as factors influencing their respective quality of sleep. Therefore, implementing a well-timed nap structure becomes a priority for all healthcare professionals exposed to the risk of sleep restrictions due to night duties.

Limitations

Our study was conducted at a single tertiary-care hospital,which limits the generalisation of results to other institutions. The majority of the participants were female, with a median age of 22 years so conclusions can be drawn only for this age group. Analysis of experimental groups without gender comparison and biomarkers of circadian rhythm would have better corroborated the study.

CONCLUSION

Our study not only underscores the challenges posed by different sleep patterns on cognitive functions but also advocates for tailored strategies, such as strategic napping, to mitigate the detrimental effects. This is particularly crucial in demanding professions like nursing, where optimal cognitive performance is paramount, especially during night shifts.

Our study points toward a deteriorated sleep quality as projected by a PSQI global score, greater tendency toward sleepiness (KSS score), and reduced positive affect in the partial sleep-restricted group. This is also supported by reduced abstraction and encoding and retrieval of declarative memory in the partial sleep restriction group. This implies that professions in the healthcare system, like nursing, which require utmost precision and vigilance and hence are memory dependent, are related to sleep for their optimal function.

Acknowledgments

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Ethical approval

The research/study approved by the Institutional Review Board at Jawaharlal Nehru Medical College Institutional Ethics Committee, number MDC/JNMCIEC/376, dated 16/10/2023.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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