Original Article

Access this article online
Quick Response Code:
Website:
www.jehp.net
DOI:
10.4103/jehp.jehp_1602_23

Impact of sleep deprivation on stress levels and cognitive performance in young and middle-aged adults at a Medical University in Ajman, UAE

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Abstract:

BACKGROUND: Inadequate sleep is a widespread public health concern, impacting physical and mental health, as well as cognitive well-being. This study explores the link between sleep quality, the inflammatory marker interleukin-6 (IL-6), and cognitive function in two age groups (18-25 years and 35 years and above) at Gulf Medical University.

MATERIALS AND METHODS: Sleep quality was assessed using the Pittsburgh questionnaire, and salivary IL-6 levels were measured. Cognitive function was evaluated using the National Aeronautics and Space Administration-Psychomotor Vigilance Test (NASA-PVT), focusing on mean reaction time (RT), lapses, fastest 10% RT, and slowest 10% RT. Descriptive and inferential statistics were used to analyze the data. The descriptive statistics used were frequency, percentage mean, and standard deviation (SD). The inferential statistics used was the unpaired *t*-test. The level of significance was taken as $P \leq 0.05$. Statistical Package for the Social Sciences (SPSS) 28 was used to analyze the data.

RESULTS: Approximately 75% of young adults and 80% of middle-aged adults reported good sleep quality. Sleep disturbances were reported by 65% of young adults and 95% of middle-aged adults. In both age groups, individuals with poor sleep exhibited higher IL-6 levels, but all IL-6 values remained within the reference range. NASA-PVT results indicated that individuals with poor sleep had higher mean RT and lapses compared to those with good sleep. In the older age group, both mean RT and lapses were higher than in the younger group, suggesting potential age-related effects on psychomotor vigilance.

CONCLUSION: Our findings suggest a connection between poor sleep quality, elevated IL-6 levels, and impaired cognitive performance.

Keywords:

Cognitive function, inflammatory marker, interleukin-6, psychomotor vigilance, sleep

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Received: 06-10-2023
Accepted: 02-01-2024
Published: 29-07-2024

Introduction

Insufficient sleep has become a serious public health concern, particularly prevalent among students.[1,2] To many, sleep may appear as unproductive dormancy, time that could be more profitably allocated to other pursuits. As a result, individuals often sacrifice sleep to meet work, educational, or societal obligations.[3,4] However, research has shown that unhealthy sleep patterns not only impact individuals physically and emotionally but also have adverse effects on cognitive well-being. Circadian rhythm disturbances lead to alterations in hormones and inflammatory markers, potentially compromising attention and decision-making in sleep-deprived

How to cite this article: Shaikh SA, Alintakli F, Mohamed M, Mohammed M, Khanam R, Shetty PJ. Impact of sleep deprivation on stress levels and cognitive performance in young and middle-aged adults at a Medical University in Ajman, UAE. J Edu Health Promot 2024;13:254.

individuals.[1] Beyond its physical and mental health implications, sleep deficiency can disrupt the academic performance of college students.[5] Furthermore, numerous professions, including military personnel, shift workers, and medical residents, frequently endure inadequate sleep. Scientific research on the consequences of sleep deprivation is essential for enhancing the health and performance of individuals who must excel in conditions of minimal sleep.[3]

As individuals age, sleep patterns undergo significant changes, both at the macro-level (e.g., sleep duration, stages) and micro-level (e.g., sleep oscillations).[6] Aging is associated with more fragmented and lighter sleep, characterized by increased arousals and awakenings.[7] In young adults, slow wave sleep (SWS) is most prominent in the first non-rapid eye movement (NREM) cycle of the night, gradually diminishing over subsequent NREM cycles. This reflects a homeostatic dissipation of sleep pressure.[6] However, middle age marks a reduction in SWS (stages 3 and 4), with some evidence suggesting its complete absence beyond the age of 90. Compensatory increase occurs in the duration of stages 1 and 2, while REM sleep decreases proportionally with total sleep time reduction. Sleep efficiency also decreases with age, accompanied by an increased frequency of sleep stage shifts.[7] Research by Van Cauter *et al*. (2000)[8] revealed a decline in total sleep time by approximately 27 min per decade from mid-life to the eighth decade in men aged 16–83. In addition, self-reported studies on older adults have linked poor and shorter sleep to cognitive impairment across various tests, including verbal memory encoding.[9]

Gender, especially in later life, is a factor influencing sleep quality. Men tend to experience more pronounced disruptions and impairments in NREM sleep as compared to women. This distinction was observed in a study comparing over 2,500 older adults aged 37–92.[10]

Sleep deprivation, characterized by a diminished ability to initiate and maintain sleep, has been linked to cognitive energy resource reduction. These resources are essential for selecting appropriate emotional regulation strategies under challenging conditions.[11] The effects of sleep deprivation on cognition are both global and specific, most consistently manifesting as reduced attention and psychomotor vigilance, along with increased behavioral response variability. These effects are associated with altered functioning of the dorsolateral prefrontal cortex and parietal regions. The longer an individual remains awake, the greater the biological pressure for sleep. During periods of intentional wakefulness, the accumulating homeostatic pressure for sleep conflicts with the individual's motivation to stay awake.[3]

Inflammation has emerged as a key link between sleep duration, sleep disorders, and various health conditions. In response to stressors, inflammatory proteins are released into the bloodstream, serving as valuable biomarkers, and providing insights into their effects on bodily functions.[12] The cognitive effects of acute and chronic sleep deprivation can vary. It has been reported that acute sleep deprivation primarily affects physical but not cognitive ability in young, healthy university students.[13]

Inflammatory cytokines, including interleukin (IL)-6, play critical roles in inflammatory disorders but have complex functions and interactions. They serve as targets for therapies and biomarkers for disease detection and progression. Various cytokines, such as IL-6, IL-1, IL-33, tumor necrosis factor (TNF)-alpha, IL-10, and IL-8, are involved in inflammatory responses.[14] These small proteins are produced by nearly all cells to regulate immune responses.[15] Pro-inflammatory cytokines initiate immune cell activation, further cytokine release, and have been associated with conditions such as shock, trauma, immunological dysregulation, osteoporosis, and severe illness.[14,15] Recent research suggests that a balanced immune response requires simultaneous pro- and anti-inflammatory cytokine release.[16]

IL-6, produced by T-cells, monocytes, endothelial cells, and fibroblasts, has both pro- and anti-inflammatory properties and is involved in various biological processes. It can signal through two mechanisms: binding to the membrane-bound IL-6 receptor (mbIL6R) and recruiting glycoprotein 130 (gp130) for downstream signaling or binding to the soluble IL-6 receptor (sIL6R), leading to trans-signaling in cells lacking mbIL6R. It is used as a biomarker to monitor inflammation levels in various conditions, including cancer, infection, and autoimmune diseases.[17] It has prognostic value in diseases like pancreatic and cardiovascular diseases, helping to distinguish infection from fever of unknown origin.[18]

Chronic low-grade inflammation is frequently observed in aging individuals, arising from medical conditions, psychological factors, and lifestyle choices. Elevated IL-6 levels have been linked to inflammatory diseases and can contribute to sleep-related symptoms and fatigue. Conversely, alterations in sleep duration and quality can increase IL-6 concentrations. Psychological stress, both acute and chronic, can also elevate IL-6 levels, highlighting the intricate connection between physiological and psychological disruptions.[19]

The Psychomotor Vigilance Test (PVT) is a widely used tool to assess alertness and vigilance, particularly in sleep deprivation and circadian disruption studies. The

5-minute version, validated as a fatigue assessment tool, is a practical choice for non-laboratory situations.[20] The National Aeronautics and Space Administration (NASA) with increasing wakefulness, particularly after 16 h and reaching its lowest point after 24 h. These findings underscore the need for reliable and practical tools to assess fatigue in field studies.[21] Hence, it was essential to explore the potential association between cognitive performance and inflammatory markers in sleep-deprived individuals, encompassing both young and middle-aged populations.

Materials and Methods

Study design and setting: The study participants were selected from the Gulf Medical University, Ajman community, based on predefined inclusion criteria. They were invited to participate in the research and were asked to complete the Pittsburgh Sleep Quality Index (PSQI) questionnaire, during which information regarding the study's procedures and potential benefits was provided.

Study participants and sampling: Following questionnaire analysis, eligible participants were informed about their selection for sample collection. Detailed explanations of the inclusion and exclusion criteria were given, and informed consent was obtained prior to sample collection. In addition, participants were asked to undergo a simple PVT using an iPad provided to them.

Data collection tool and techniques

Saliva Sample Collection: Participants were provided with 1 mL vials suitable for saliva collection and instructed to provide a fasting saliva sample in the morning through passive drooling. These saliva samples were promptly stored at –20°C until they were needed.

Interleukin-6 (IL-6) Estimation by Enzyme-linked Immunosorbent Assay (ELISA): IL-6 levels were measured using the Salimetrics® IL-6 ELISA Kit. Saliva samples were thawed, centrifuged, and processed according to the kit's instructions. The ELISA plate's optical density was read at 450 nm, and necessary calculations were performed to determine the final IL-6 concentration in the samples. This assay is based on a sandwich ELISA principle, where the microtiter plate contains anti-IL-6 antibodies that bind to IL-6 in the samples. Subsequent steps involve the addition of biotin-conjugated antibodies and the reaction with streptavidin conjugated to horseradish peroxidase (HRP). The resulting color change is measured at 450 nm, with the amount of HRP detected being proportional to the IL-6 concentration. Reference Range for IL-6: 1.27–5.37 pg/mL.

Ethical considerations

Prior to the commencement of data collection and research activities, ethical clearance was obtained from the Gulf Medical University Institutional Review Board (IRB)] under reference number IRB/COM/STD/45/JULY-2022.

Descriptive and inferential statistics were used to analyze the data. For categorical variables, we have calculated the frequency and the percentages, and the continuous variables, we have calculated the mean and the standard deviation. For testing the hypothesis, in the present study, we have two groups, and the sample size of each group is small; hence, we have used an unpaired t-test. The level of significance was taken as $P \leq 0.05$. Statistical Package for the Social Sciences (SPSS 28) was used to analyze the data.

Results

Based on the responses to the administered questionnaire and the demographic data collected, the study yielded the following results for both young and middle-aged participants:

Young adults

Most participants in this group were female, accounting for 75% of the total. 75% of young adults reported having good sleep quality. A significant 80% reported sleep latency periods of less than 30 min, indicating a relatively quick time to fall asleep. 75% of participants reported having more than 6 h of sleep, with 45% getting more than 7 h, suggesting a reasonably adequate sleep duration. Habitual sleep efficiency, as reported by 65% of participants, was greater than 85%, indicating effective sleep patterns. Approximately 65% of the young adults reported experiencing minimal sleep disturbances (0/1 sleep disturbances). Many participants (90%) did not rely on any medication to aid their sleep [Table 1].

Middle-aged adults

In the middle-aged group, most participants were also female, constituting 60% of the total. A significant 80% of middle-aged adults reported having good sleep quality. An impressive 90% of participants in this group reported sleep latency periods of less than 30 min, indicating a quick onset of sleep. 70% reported having more than 6 h of sleep, with 30% getting more than 7 h, suggesting an adequate sleep duration for this age group. Habitual sleep efficiency, as reported by 65% of middle-aged adults, was greater than 85%, reflecting effective sleep patterns. An overwhelming 95% of the middle-aged population reported experiencing sleep disturbances less than once a week. The majority of middle-aged participants (80%) did not use any medication to aid their sleep [Table 1].

Table 1: Pittsburgh Sleep Quality Index (PSQI) scoring for the young adult and middle-aged adult participants. The PSQI questionnaire comprises 7 components that are to be measured separately. The global PSQI score is obtained from the sum of the 7 components

Variables	Category	Young adults characteristics (%)	Middle-aged adults characteristics (%)
Age limit		18–25 years	35–45±5 years
Ethnicity	Asian - 70%	70%	75%
	Arab - 30%	30%	25%
Gender	Males	5 (25%)	8 (40%)
	Females	15 (75%)	12 (60%)
C1 - Subjective sleep quality	Very good	3 (15%)	4 (20%)
	Fairly good	12 (60%)	12 (60%)
	Fairly bad	3 (15%)	3 (15%)
	Very bad	2 (10%)	1 (5%)
C2 - Sleep latency	0 (< 15 mins)	8 (40%)	10 (50%)
	1 (16–30 mins)	8 (40%)	8 (40%)
	2 (31–60 mins)	2 (10%)	2 (10%)
	3 (>60 mins)	2 (10%)	0
C3 - Sleep duration	>7 h (0)	9 (45%)	6 (30%)
	6–7 h (1)	6 (30%)	8 (40%)
	5–6 h (2)	1 (5%)	4 (20%)
	<5 h (3)	4 (20%)	2 (10%)
C4 - Habitual sleep efficiency (Total hours slept/Total hours in bed) ×100	>85% (0)	13 (65%)	13 (65%)
	75–84% (1)	3 (15%)	3 (15%)
	65–74% (2)	2 (10%)	3 (15%)
	<65% (3)	2 (10%)	1 (5%)
C5 - Sleep disturbances	0 (Not during the past month)	1 (5%)	3 (15%)
	1 (Less than once a week)	12 (60%)	16 (80%)
	2 (Once or twice a week)	6 (30%)	1 (5%)
	3 (Three or more times a week)	1 (5%)	0
C6 - Use of sleeping medicine	Not during the past month (0)	18 (90%)	16 (80%)
	Less than once a week (1)	0	2 (10%)
	Once or twice a week) (2)	1 (5%)	1 (5%)
	Three/more times a week (3)	1 (5%)	1 (5%)
C7- Daytime dysfunction Question 7 + Question 8	0	6 (30%)	7 (35%)
	1	5 (25%)	6 (30%)
	2	7 (35%)	6 (30%)
	3	2 (10%)	1 (5%)

Inflammatory marker

In both age groups, the study measured the levels of IL-6. The findings showed that individuals classified as poor sleepers had higher IL-6 levels compared to those classified as good sleepers. However, it is worth noting that the IL-6 values for all participants, whether they had good or poor sleep, fell within the reference range [Table 2].

Table 2: Laboratory results of salivary IL-6 levels

Subjects	Sleep quality	IL-6 (pg/ml)	*P*
Young adults	Good	1.41±0.27	NS* (0.13)
	Poor	1.56±0.13	
Middle-aged adults	Good	1.22±0.27	NS* (0.07)
	Poor	1.52±0.42	

IL-6=Interleukin-6. NS* - The level of significance was taken as $P \leq 0.05$, which is non-significant

Psychomotor vigilance test (PVT) results

The study analyzed the results of the PVT and focused on four key parameters: Mean reaction time (RT), lapses, fastest 10% RT, and slowest 10% RT. The findings revealed that individuals with poor sleep exhibited higher values for mean RT and lapses compared to those with good sleep [Table 3]. In addition, within the older age group, both mean RT and lapses were higher when compared to the younger participants, suggesting a potential age-related impact on psychomotor vigilance.

Discussion

The results of our study provide valuable insights into the sleep patterns, inflammatory marker levels, and cognitive performance of both young and middle-aged adults. These findings contribute to a deeper understanding of the complex relationship between sleep quality,

Table 3: Mean values for sleep quality among the two groups using NASA-PVT

Subjects	Sleep quality	NASA-PVT			
		Mean RT	Lapses	Mean fastest 10%	Mean slowest 10%
Young adults	Good	250.94±25.25	0.9±0.876	263.28±11.88	493.01±124.30
	Poor	262.03±53.27	2.4±3.74	264.98±28.62	499.46±114.84
P		NS* (0.55)	NS* (0.23)	NS* 0.86	NS* 0.90
Middle-aged adults	Good	265.83±36.58	3.1±2.88	270.76±27.80	503.19±81.39
	Poor	278.08±44.96	3.6±3.92	278.14±27.23	535.9±99.054

NASA-PVT=National Aeronautics and Space Administration-Psychomotor Vigilance Test. NS* - The level of significance was taken as $P \leq 0.05$, which is non-significant

inflammatory markers, and cognitive function across different age groups.

In the young adult population, we observed a predominantly female composition (75%), which aligns with existing research highlighting gender differences in sleep patterns and sleep-related disorders.[22] In addition, a substantial 75% of young adults reported good sleep quality, emphasizing that a considerable proportion of this age group enjoys a restful night's sleep [Table 1]. This finding is encouraging, as quality sleep is fundamental for physical and mental well-being, especially during the formative years of adulthood.[23]

Moreover, the majority (80%) of young adults reported a sleep latency of less than 30 min, indicating a prompt transition into sleep. This rapid onset of sleep is indicative of healthy sleep initiation, which is essential for overall sleep quality.[24] It is noteworthy that a significant portion (45%) of young adults reported obtaining more than 7 h of sleep, fulfilling the recommended 7–9 h of sleep for this age group.[25] This suggests that a substantial proportion of young adults are prioritizing adequate sleep duration.

Habitual sleep efficiency, a measure of how effectively one's sleep time is utilized, was reported as greater than 85% by 65% of young adults. This underscores the presence of effective sleep patterns within this age group. Furthermore, the prevalence of minimal sleep disturbances (0/1 sleep disturbances) among approximately 65% of young adults is a promising indicator of the overall sleep quality in this demographic. In addition, the fact that 90% of young adults do not rely on sleep medication highlights their ability to achieve good sleep without pharmacological aids.

In the middle-aged adult population, we also noted a predominant female representation (60%), which mirrors the gender distribution observed in the young adult group. It is worth noting that 80% of middle-aged adults reported good sleep quality, reaffirming the importance of sleep quality maintenance across the lifespan [Table 1]. Furthermore, an impressive 90% reported sleep latency periods of less than 30 min, indicating that middle-aged adults, like their younger counterparts, generally experience a quick onset of sleep.

Approximately 70% of middle-aged adults reported having more than 6 h of sleep, with 30% obtaining more than 7 h. These figures suggest that, on average, middle-aged adults in our study are achieving reasonably adequate sleep duration. Similar to young adults, 65% of middle-aged adults reported habitual sleep efficiency greater than 85%, indicating effective sleep patterns. Importantly, an overwhelming 95% of middle-aged individuals reported experiencing sleep disturbances less frequently than once a week, underscoring their ability to maintain relatively undisturbed sleep.

Moreover, a significant majority (80%) of middle-aged participants did not use any sleep medication, indicating that most individuals in this age group can achieve good sleep without the need for pharmacological interventions.

One of the central aspects of our study was the measurement of IL-6 levels in both age groups. Our findings demonstrated that individuals classified as poor sleepers had elevated IL-6 levels compared to their counterparts classified as good sleepers [Table 2]. This observation aligns with previous research linking sleep disturbances to increased inflammatory marker levels.[26]

Notably, despite the differences in sleep quality, it is essential to highlight that the IL-6 values for all participants, whether they were classified as good or poor sleepers, fell within the reference range. This suggests that the observed elevations in IL-6 among poor sleepers did not surpass clinically significant thresholds. However, the presence of higher IL-6 levels in poor sleepers still underscores the potential impact of sleep quality on inflammatory responses.

Our study also delved into cognitive performance through the analysis of PVT results. We specifically examined mean RT, lapses, fastest 10% RT, and slowest 10% RT as key parameters. The findings revealed that individuals with poor sleep exhibited prolonged mean RT and a higher frequency of lapses compared to those with good sleep [Table 3]. These results are consistent with existing literature highlighting the adverse effects of sleep deprivation on attention and psychomotor vigilance.[27]

Moreover, within the middle-aged group, we observed that both mean RT and lapses were more pronounced compared to the younger participants. This suggests a potential age-related impact on psychomotor vigilance, with middle-aged adults being more susceptible to the cognitive effects of poor sleep. This finding underscores the importance of addressing sleep quality and sleep-related issues in middle-aged individuals to mitigate potential cognitive impairments.

In summary, our study sheds light on the intricate relationship between sleep quality, inflammatory markers, and cognitive performance in both young and middle-aged adults. These findings provide valuable insights into the diverse sleep patterns and their impact on health and cognitive function across different age groups.

Our examination of sleep quality and patterns revealed that a substantial proportion of young adults enjoy good sleep quality, with many achieving recommended sleep durations. Notably, these young adults displayed effective sleep initiation and minimal sleep disturbances, further emphasizing the importance of quality sleep during the formative years of adulthood. In addition, the majority did not rely on sleep medication, indicating their ability to attain restful sleep naturally. Among middle-aged adults, similarly positive sleep patterns were observed, reinforcing the significance of maintaining good sleep quality throughout one's life.

The assessment of inflammatory markers uncovered that those individuals characterized as poor sleepers exhibited elevated IL-6 levels, aligning with previous research linking sleep disturbances to increased inflammation. Importantly, IL-6 values for all participants remained within the reference range, emphasizing that these elevations did not reach clinically significant thresholds. Nevertheless, the findings underscore the potential influence of sleep quality on inflammatory responses.

Regarding cognitive performance, our analysis of the PVT demonstrated that individuals with poor sleep exhibited longer mean RT and a higher frequency of lapses compared to their well-rested counterparts. These outcomes are consistent with existing literature highlighting the detrimental effects of sleep deprivation on attention and psychomotor vigilance. Moreover, middle-aged adults, in particular, displayed more pronounced impairments, indicating a potential age-related susceptibility to the cognitive consequences of poor sleep.

Limitations and recommendation

While our study provides valuable insights, several limitations should be considered. First, the study's cross-sectional design restricts our ability to establish causality between sleep quality, inflammatory markers, and cognitive performance. Longitudinal studies would be necessary to explore these relationships more comprehensively over time. Second, the study relied on self-reported sleep data, which may introduce recall bias and subjectivity. The inclusion of objective sleep measures, such as polysomnography or actigraphy, could enhance the accuracy of sleep assessments. Third, our study sample was drawn from a specific geographic region and may not represent broader population diversity. Expanding the study to encompass more diverse demographics would enhance the generalizability of the findings. Fourth, while IL-6 was investigated, other inflammatory markers and hormones relevant to sleep and health could be explored in future studies to provide a more comprehensive understanding of the underlying mechanisms. Lastly, the PVT is just one tool for assessing cognitive performance. Future research could incorporate a broader battery of cognitive tests to capture a more comprehensive picture of cognitive function.

Conclusion

In conclusion, our study provides valuable insights into the sleep patterns, inflammatory marker levels, and cognitive performance of both young and middle-aged adults. The results highlight the importance of maintaining good sleep quality across the lifespan and its potential influence on inflammatory markers and cognitive function. Further research is warranted to explore the mechanisms underlying these associations and to develop interventions aimed at improving sleep quality and mitigating its adverse effects on health and cognitive performance.

Acknowledgements

We thank Prof. Jayadevan Sreedharan for providing statistical support for data analysis.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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