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Original Article

Effects of Changes in Sleep Rhythm on Cognitive Functions in Clinical Residents

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Abstract

Background and Aim: Adequate sleep is considered as one of the physiological needs of human beings. In addition to adverse effects on physical and mental health, inadequate sleep can affect cognitive functions as well. Since night shifts are part of the main tasks of most clinical residents and are followed by changes in their sleep rhythm, this study investigated the changes in cognitive functioning of clinical residents following night shift work.

Materials and Methods: This descriptive-correlational study was conducted by convenient sampling method. So, 104 clinical residents were selected from seven different clinical specialties at Shahid Beheshti University of Medical Sciences hospitals. In order to investigate the cognitive function of the residents, the Demographic Questionnaire and Cognitive AbilitiesQuestionnaire were used in the beginning and end of the shifts. Data were analyzed using SPSS software and statistical tests such as the Paired T-test, Wilcoxon, independent T-test, the Spearman and Mann-Whitney.

Results: According to statistical analysis, the mean score of memory scale at the end of the shift work was significantly different between different specialties ($P<0.05$). The difference in memory score changes at the end of the shift, compared to the beginning of the shift, in non-surgical specialties was significant ($P<0.05$). It was also found that a significant relationship existed between the overnight sleep in the shift and the memory scale at the end of the shift ($P<0.05$).

Conclusion: In this study, findings showed that night shift in various parameters, such as inadequate and inappropriate sleep, has caused changes in some cognitive function scales in different academic years and different clinical specialties. Differences in workload, job stress level, coping mechanisms and responsibility level could be the main reasons for these differences in different academic years and clinical specialties.

Keywords: Clinical Resident, Cognitive Function, Shift Work, Sleep

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Introduction

Medical errors are one of the challengeable problems of the countries' health care systems and allocate a significant burden and cost (1). Based on estimates, about 251,000 people die annually in United States hospitals due to medical errors, and according to the US Centers for Disease Control and Prevention (CDC), medical errors are the third leading cause of death in the United States (2, 3). Based on the research, one of the important reasons for these errors is related to fatigue caused by night shifts and long working hours (4, 5).

For the first time in 1971, in a study conducted by Freidman et al., showed that medical interns had more errors in the interpretation of the electrocardiogram (EKG) and the diagnosis of arrhythmias after the night shift (6, 7). After this study, several studies were conducted regarding the effects of the night shift on the performance and health of doctors and medical students, as well as the subsequent impacts on the patients (6). Studies like investigating the effects of the night shift on the performance of the intensive care units physicians, which showing the longer time of intubation in night shifts compared to daily working hours, more medical errors of intensive care unit's clinical residents in 24-hour shifts compared to shorter shifts (8), and weaker clinical management of residents in simulation scenarios of critically ill patients after long-term wakefulness (9) was one of these case.

Other studies have also investigated the effects of night shifts on the cognitive performance of people in non-medical jobs. Kazemi et al. examined the effect of day and night shift works on cognitive function, sleep quality and sleepiness of 60 control room operators of a petrochemical complex. Therefore, the results of this study showed that long working hours in work shifts can lead to fatigue, irregularity in the circadian cycle and sleep cycle, and a decrease in cognitive performance at the end of both day and night shifts, and an increase in the feeling of sleepiness after the night shift (10).

Adequate and appropriate sleep is one of the physiological needs of human beings and is an effective factor related to health and survival (11). Appropriate sleep regulates the cardiovascular system, such as blood pressure and heart rate. It also could regulate the secretion of hormones, cell repair, function of the defense system, and cognitive function (12). However, the impact of inadequate sleep on cognitive function is controversial (6, 13). Some studies have pointed to the impact of chronic inadequate sleep on cognitive performance, while other studies have shown these effects even in short-term inadequate sleep (14).

Studies have also shown that chronic inadequate sleep of less than 7 hours a night is associated with obesity, diabetes, cardiovascular disorders, hypertension, anxiety, and mood disorders such as depression and alcohol abuse (15, 16).

Cognitive function includes different mental abilities such as attention, information processing speed, and working memory that all playing an important role in executive function of individuals in their daily activities and different jobs (10, 17, 18). Therefore, if cognitive function decline, even temporarily, it can have negative consequences and adverse effects on individual's performance, especially, among physicians who need accuracy and speed while preforming their tasks (10, 14). It seems that working long hours at night with inadequate sleep leads to dysfunction, reduced psychomotor functions, complex problem-solving power, mood changes, and reduced learning of complex cognitive tasks (19).

It appears inadequate sleep could affect cognitive and memory functions by impacting the plasticity of neurons and the neurogenesis process. Mechanisms such as weakening the intracellular adenosine monophosphate -protein kinase A (cAMP-PKA) signaling, which leads to changes in the gene expression of cAMP response element binding protein (CREB), neurotrophic signaling and glutamate receptor gene expression are some of the pathways involved in these processes (13).

Due to the effect of cognitive functions on the daily executive functioning of individuals, cognitive function decline is one of the factors that can cause work errors (19). Therefore, cognitive function can be a good index in relation to investigating the effects of shift work and inadequate sleep on the functions of an individual.

The sleep deprivation prevalence among university students is high. Although, based on the studies, approximately 71 % of university students slept less than 8 hours, limited studies have concentrated on this issue and its consequence in this group (12).

Medical residents, as a group of medical staff, are prone to fatigue and chronic lack of sleep due to long working hours, rotational work schedules and shifts (20, 21). Therefore, this group of individuals may, in the long run, be exposed to problems caused by lack of sleep due to night shifts and are physically and mentally endangered (22) .

Considering many effects of night shift work on different individuals, in this study, we attempted to investigate the effects of night shifts on changes in cognitive function of clinical residents. Although several studies have addressed the effects of shifts on cognitive and executive function of individuals, during the review of various studies it was found that this issue has not been addressed comprehensively in Iran, so due to racial, personal, cultural, economic, and political differences, this issue was important and needed to be investigated. Also, many studies have been conducted in limited groups and specialties but in this study, we have investigated and compared the effects of the shift work on cognitive function of residents in seven clinical specialties, including surgical and non-surgical.

Methods

The present study was a descriptive-correlational study investigating changes in cognitive function of residents before and after their shifts in different years of their training and from 7 different clinical specialties, including internal medicine, obstetrics and gynecology, general surgery, neurology, pediatrics, orthopedics, and psychiatry at Shahid University of Medical Sciences.

The study was carried out in accordance with the latest version of the Declaration of Helsinki. Also, the study was approved by the Ethics Committee of the Shahid Beheshti University of Medical Sciences (references code. IR.SBMU.MSP.REC.1399.136). All residents participated in the study voluntarily and the general aims of the study were briefly explained to them. Informed consent was obtained from all participants. Also, all research ethics issues were considered. They were also allowed to leave the study if they did not wish to continue participating in study. Inclusion criteria considered clinical residents at different educational levels (first-year, second year and third-year resident), shift work as tasks defined in the educational program, and willingness to participate in the research. The exclusion criteria were obvious physical or psychiatric diseases, history of drug, stimulant and alcohol abuse, unwillingness to cooperate in the research, and lack of shift work. 104 residents from different specialties from the abovementioned 7 fields, with an average of n = 15, were chosen randomly from each specialty.

Materials

Nejati Cognitive Abilities Questionnaire

In this study, the Dr. Nejati Cognitive AbilitiesQuestionnaire (23) on a 5-point Likert scale (from 1 = almost never to 5 = almost always) was used at the beginning and end of the shifts and included 7 subscales of memory, inhibitory control and selective attention, decision making, planning, sustained attention, social cognition, and social flexibility as well as total cognitive function. According to the interpretation method of this questionnaire, it is mentioned that Cognitive Function Scales and Total Cognitive Function, except Social Cognition Scale, have inverse scoring. This means that an increase in the scores of these scales indicates a reduction in that scale. The psychometric features of this questionnaire have shown proper validity and reliability for cognitive assessment (23).

Demographic Questionnaire

Another questionnaire was also used to record demographic information and investigate the number of hours of sleep at night and day and the number of sleep interruption during the night in non-shift time. In addition, a questionnaire was used to investigate number of hours of sleep and number of sleep interruption with the number of outpatients and inpatients visited, and the number of outpatient and operating room surgeries. The pre-shift questionnaire was completed by the resident at the beginning of their shift (13 to 15 hours on the day shift) and the end-of-shift questionnaire was completed by the same person at 8 to 10 a.m. next morning.

It should be noted that Cronbach's alpha of the questionnaires used in this study was calculated to be 0.88, so the questionnaires used were the high valid and reliable questionnaires.

In this study, the data were analyzed using SPSS software version 20. The Paired T-test was used to compare the mean scores of the subscales of cognitive function and the mean scores of total cognitive functions at the beginning and end of the shifts. The Wilcoxon test was used to compare the mean scores of the cognitive function scales of different academic years in each field, and an independent T-test and Mann-Whitney test were used to investigate the relationship between demographic information and cognitive function. The Spearman Correlation Test was also used to investigate correlation between cognitive function and the sleep rate and number of patients visited. P value < 0.05 was considered statistically significant and the Spearman correlation coefficient below 0.3 was considered weak.

Results

104 clinical residents from seven different specialties and at different academic years in their training participated in this study. The average age of the participants was 30.71 ± 4.33 (age range between 26 to 56 years). 44.2% of the participants were male, and the rest were female. 47.1% were married, and 52.9% were single. 39.5% of the participants were first-year, 36.5% were second-year, and 24% were third-year residents. Features of the sleeping hours and workload of participating residents were shown in table 1.

Using an independent T-test, it was found that only the mean score of sustained attention at the end of the shift was significantly different between men and women residents (p = 0.02) and was higher in women (8.793 vs 7.413).

Using the Spearman Correlation Test, it was found that a significant relationship and correlation existed between some subscales and total cognitive function with some demographic information, as seen in Table 2. Also, no significant relationship was observed between daily total sleep at non-shift time and the number of outpatient and in the operating room surgeries in shift time with subscales and total cognitive function at the end of the shift (P> 0.05).

The results of analysis of variance showed that the mean score of cognitive function scales in different discipline at the end of the shift was significant only on the memory scale (p = 0.04) so that the mean score in the psychiatric group was the lowest (9.53) and the orthopedic group was higher than the others (14.29).

According to the results of the Wilcoxon test, it was found that the mean score of inhibitory control and selective attention at the end of the shift was significantly different from the beginning of the shift only in the first-year residents of pediatrics (p = 0.03). The difference in

Table 1: Features of sleeping hours and workload of participating residents.

Duration of night sleep during non-shift time (hours)	6.39±1.26 (min. 4h & max. 10h)
Duration of day sleep during non-shift time (hours)	1.32±1.17 (min. 0h & max. 7h)
Average number of night sleep interruption during non-shift time	1.26±1.43 (min. 0 times & max. 8 times)
Duration of night sleep during shift time (hours)	3.26±1.87 (min. 0h & max. 8h)
Average number of night sleep interruption during shift time	2.69±2.35 (min. 0 times & max. 11 times)
Average number of inpatient visits during shift time	8.95±8.27 (min. 0 & max. 60)
Average number of outpatient visits during shift time	12.18±22.30 (min. 0 & max. 120)
Average number of outpatient surgery	0.54±1.08 (min. 0 & max. 4)
Average number of surgeries in operating room	1.28±2.87 (min. 0 & max. 15)

Min= minimum, max=maximum, h= hour

Table 2: Investigating the Relationship between Demographic variable and Cognitive Performance scales of Clinical residents.

Variables	Memory	Inhibitory Control and Selective Attention	Decision making	Planning	Sustain Attention	Social Cognition	Cognitive Flexibility	Total Cognitive Function
Age						0.2*		
Duration of night sleep during non-shift time	-0.22*						-0.23*	-0.24*
Average number of night sleep interruption during non-shift time							0.23*	
Duration of night sleep during shift time	-0.2*							
Average number of night sleep interruption during shift time	0.19*	0.3*					0.31*	0.22*
Average number of inpatient visits during shift time		0.21*			0.21*			0.22*
Average number of outpatient visits during shift time						0.23*		

*P<0.05

the mean score of sustained attention at the beginning and end of the shift was significant only in the second year of pediatrics ($p = 0.04$). It was also found that the difference in the mean score of cognitive flexibility was significant at the beginning and end of the shift only in the second year of surgery ($p = 0.04$). The difference between the mean scores of total cognitive functions at the beginning and end of the shift was only significant in third year resident obstetricians and first year resident pediatricians ($p < 0.05$), but it was found that the mean scores at the end of the shift in residents in different academic years (comparing the sum of year one, year two, and year three) was not significantly different.

The results of paired T-tests showed that the difference in the mean score of memory in the non-surgical disciplines (internal medicine, neurology, pediatrics, and psychiatry) was significant at the end of the shift compared to the beginning of the shift ($p = 0.048$).

Discussion

According to the results in the present study, comparative scores of the cognitive function of residents in two groups of men and women at the beginning and end of their shifts found that only the mean scores of sustained attentions at the end of the shift in these two groups were significantly different and were higher in the female group. According to the interpretation method of the questionnaire, this means that women had less sustained attention at the end of the shift than men and the criterion of sustained attention at the end of the shift is somewhat affected by gender. A study by Hajali et al. (24) has also shown that inadequate sleep is more effective on cognitive function of women than of men. In the study, the effect of sex hormones, physiological differences in sleep and sleep stages, as well as differences in circadian rhythm in these two groups are mentioned as the reason for observing the difference in cognitive function after inadequate sleep (24). In our study, it was also found that a significant and direct relationship prevailed between the age of residents and the mean criterion of their social cognition at the end of the shift, which means that the older person had better social cognition after the shift. A study by Alhola et al. found that older individuals were more adapted to insomnia and longer night waking hours than younger individuals and their cognitive and executive function was less impaired. It was also noted that they have faster function recovery than younger individuals. Therefore, it seems that this difference in this group is due to the change and weakening of the fluctuation of the circadian system in older individuals and the role of the homeostasis and physiological mechanisms, whereas, it could also result from their greater experience in adapting to the challenges of inadequate sleep (25). Other reasons for this finding include a reduction in the need for sleep with increasing age and an easier return to sleep after waking up in the shift by being paged or the ringing of their phone, or after long wakefulness due to more experiences in this type of job (8). It was also found that a significant and inverse relationship occurred between overnight sleep during non-shift hours and memory, cognitive flexibility, and total cognitive function at the end of the shift. Therefore, this result indicates that the longer overnight sleep during non-shift hours improved the memory, cognitive flexibility, and total cognitive function of the person during post shift. Among the reasons justifying this finding is a theory related to the essential role of sleep in active processes and recovery of mental functions such as growth, memory and information retrieval process, as well as the role of sleep in behavioral, physiological and cognitive-functional processes (26). It was hypothesized that residents with adequate sleep during the night before the shift would be better prepared during the shift, could better solve the challenges ahead on the shift, and would be less affected by the shift fatigue. Therefore, according to the definition of cognitive flexibility, which is the ability to change cognitive function to adapt to the environment and stimuli, these residents had better cognitive flexibility and function in post-shift (27). Additional results showed that if the person has less sleep overnight during the shift, they will have less intensive memory at the end of the shift. This finding is consistent with previous studies. A study by Samatra et al. (26) at Sanglah Hospital also showed that inadequate sleep of less than 7 hours during shifts, as an independent factor, can lead to cognitive decline and parameters such as memory. One of the reasons for this finding is a theory related to the essential role of sleep in the processes of recovery of mental and cognitive functions such as memory and information retrieval. Sectional Inadequate sleep can also lead to a reduction in melatonin levels, which in turn causes a reduction in ARAS inhibition causing a state of wakefulness. This reduction in melatonin and activation of the ARAS system leads to an increase in activity of the sympathetic system, followed by an increase in cortisol and IL-6 and a reduction in orexin secretion that they play a key role in cognitive function changes. It was also observed in the current study that the greater number of night sleep interruption during non-shift hours leads to weaker cognitive flexibility during the shift. The results also showed that a significant and direct relationship correlates between the number of night sleep interruption during the night shift and the memory, inhibitory control, selective attention, cognitive flexibility and total cognitive function scales of clinical residents at the end of their shift. A study by Osterode et al. (28) showed that the number of sleep interruption is strongly and inversely related to sleep quality. On the other hand, this study showed that sleep quality had a direct effect on cognitive and executive function in physicians. Therefore, the number of sleep interruption during the shift can play a role in cognitive function after the shift. For justifying the effect of the number of sleep interruption during night sleep in non-shift hours on cognitive function at the end of the shift, we can also mention similar effects of the number of night sleep interruption during non-shift hours, leading to reduced sleep quality (28). This factor probably causes cognitive vulnerability in individuals at the beginning and during the shift and can lead to a reduction in cognitive function at the end of the shift. The results also showed that more visited outpatients during the shift led to residents having a better social cognition at the end of their shift. In a study by Bakhshi et al. (29), it was observed that there was no significant relationship between nurse workload and mental fatigue. This result could possibly be due to patient visits leading to more social interactions of the residents with patients with different cultures, behavioral, and personality traits and this factor could have led to more social cognition at the end of the shift. It was also found that a significant and direct relationship was between the number of patients admitted to the hospital with inhibitory control and selective attention, sustained attention and the total cognitive function scales of clinical residents at the end of the shift. A study by ÇalişkanTür et al. found that the number of patients visited was one of the most important stressors for residents in their night shifts. The number of patients visited and the workload play an important role in creating an emotional and cognitive burden on persons in these professions. Therefore, the number of patients visited in the shift can affect the cognitive function of residents at the end of their shifts (30). Another result observed in the present study was that only the mean scores of the memory scale were significantly different between these 7 specialties at the end of the shift so that the mean score of memory at the end of the shift decreased in the groups, respectively: orthopedic (14,286), surgery (11.933), internal medicine (11.533), obstetrics and gynecology (10.813), neurology (10.733), pediatrics (10.279) and psychiatry (9.533), which according to the description of the Questionnaire means that the memory scale of the orthopedic group at the end of their shift was weaker than the other participating groups. It was also found that the memory scale at the end of the shifts declined compared to the beginning of the shifts in this group (from an average of 11.643 at the beginning of the shift to an average of 14.286 at the end of the shift, which by interpretation indicates notable memory loss). For justifying the present results, we can point to the role of stress on memory loss. The McEwen et al. study stated that stress can affect cognitive function and memory through various physiological mechanisms, especially in long term stress, such as rapid catecholamine response, its effect on beta-adrenergic receptors, increased glucose available in amygdala, and slow glucocorticoid response by neuronal loss and structural changes in the hippocampus (31). A study by Ebrahimi et al. (32) showed that the level of stress in clinical residents of different specialties is different and this stress is directly related to workload, difficulty, and type of field. In a way, surgical specialties such as obstetrics and gynecology, surgery, and orthopedics, stress higher than other non-surgical specialties such as neurology and pediatrics. In addition, results showed a significant difference in changes in the mean score of inhibitory control and selective attention only in first year training resident pediatricians at the end of their shift compared to the beginning of their shift. There was significant difference in changes only in the second-year residents training in pediatrics in the mean score of the sustained attention scale at the end of their shift compared to the beginning of their shift. Significant difference in changes in the mean score of cognitive flexibility was notable only in second year residents of surgery at the end of their shift compared to the beginning of their shift, and significant difference in changes of mean scores for total cognitive function was observed only in the third year residents of obstetrics and gynecology and first year residents of pediatrics at the end of their shifts compared to the beginning of their shifts. Studies by Deaconson et al. and Browne et al. in contrast to our study, found no significant change in the cognitive ability to learn in students and residents, and concluded that sleep disorders in this group did not have an adverse effect on functional ability (33). Since the nature of these specialist professions, workload, relative difficulty of these professions, and that the responsibility in different academic years in different specialty fields are different, in the present study we observe relative differences between different academic year studies in the different disciplines. Relative and significant difference can be justified due to the difference in responsibilities and workload of the residents in their different academic years. It was also found that the change in the mean score of the memory scale proved significant at the end of the shifts compared to the beginning of the shifts in the non-surgical group including internal medicine, neurology, pediatrics and psychiatry. In the fields of surgery, which includes general surgery, obstetrics and orthopedics, this difference was not significant (p> 0.05). A study by Amiran et al. (34) showed that inadequate sleep affects surgeons and they are aware of the effect of fatigue on their tasks, therefore, they have used different ways to adapt to their fatigue. For example, surgical instructors, due to better experience and skills, have achieved better adaptation to night shifts since their residency. Amiran et al. concluded that the effects of night shifts on surgeons are complex and multifaceted; they found no results on the effect of inadequate sleep on the psychomotor or cognition during a 17 hour shift (34), which is consistent with our results regarding the field of surgery at the end of the shift compared to before the shift. Another study by Weiss et al. on the effects of shift work on medical students stated that various studies have shown that 24-30 hours of working shifts can have an adverse effect on cognitive function and its various scales in surgical, pediatrics, anesthesia, obstetrics, and internal medicine groups. Another study found that residents of pediatrics experienced loss of memory, concentration and speed of reaction, verbal reminder, vigilance, eye-hand coordination, and attention after a 24-hour shift. However, other studies have shown that cognitive function of surgical residents with less than 2 hours of sleep per night and long shifts was not significantly different from the control group with 6.5 hours of sleep per night (35). Therefore, in the surgical groups, for the reasons mentioned earlier, compensatory mechanisms play an important role in maintaining cognitive function against fatigue and inadequate sleep due to shifts.

Limitations of the study included the COVID-19 pandemic and its effects on the increased workload of residents and less access to them, followed by sampling with a smaller number, as well as the intrinsic high workload in some specialties such as surgery. Therefore, it is suggested to conduct further research with more samples, longer time and with more equipment to analyze the subscales.

Conclusion

Investigating differences in cognitive function of residents of seven different clinical specialties at the beginning and end of the shift found that work shifts, by various parameters such as insomnia and fatigue, may cause changes in some scales of cognitive function such as memory, inhibitory control, selective attention, sustained attention, social cognition, flexibility, and total cognitive function. The “shift” has also led to changes in some scales of cognitive function between different academic years and different clinical specialties.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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