OPEN

Differential Impact of Work Overload on Physicians' Attention: A Comparison Between Residential Fields

Talya Dolev, MA, Salman Zubedat, MA,* Iris Manor, MD,† Boaz Bloch, MD,‡ Orna Blondheim, MD,‡ and Avi Avital, PhD*‡*

Objectives: Medical errors cause tens of thousands of deaths annually and have a major impact on quality of care and management; however, it receives scant research and public awareness. This study aimed to examine the relation between workload-induced lack of sleep and attention failure, as indications for medical errors risk, among young residents.

Methods: We performed an evaluation of young physicians by the Test of Variables of Attention, before and after a 24-hour shift.

Results: Workload was manifested by 13% overall attention impairment at baseline, which increased to 34% with deficiencies below the normal range after the shift. Attention measures differed between physicians of each residential field at baseline, but to greater extent after the shift.

Conclusions: Traditional working schedule is strongly associated with attention failure. Based on the literature linking attention failures to medical errors, we suggest a regulatory change regarding residents' shift duration to decrease preventable errors.

Key Words: medical error, work overload, sleep deprivation, vigilance, Test of Variables of Attention

(*J Patient Saf* 2022;18: e971–e978)

Physicians' work hours are a topic of a growing debate, culminating in national guidelines and legislation on duty hour restrictions.[1] Specifically, the long hours required during residency years are an issue of public discussion because of their harmful potential consequences in the form of medical error (ME). Medical error causes tens of thousands deaths a year[2–4] as the third leading cause of death in the United States.[5] A recent meta-analysis revealed that 5% of patients are exposed to preventable harm in medical care.[6] In Europe, the numbers reveal that ME occurs in 8% to 12% of hospitalizations. Patient harm during health care is a globally leading cause of morbidity and mortality[7,8]; thus, implementing strategies aimed to reduce the rate of ME would save approximately 100,000 lives annually.[5] Unfortunately, although ME should be a problem worthy of greater resources allocation, there is still scarcity of research on resident's work schedules and preventable adverse events.[9–11] Moreover, MEs go unreported[12] because many physicians are wary to report it[13] and experience a professional and personal disruption after an error.[14]

During residency years, there is a potential for fatigue impairment, with work schedule as a significant factor.[15] According to Landrigan et al,[16] intensive care unit (ICU) residents made more serious ME that caused harm or has the potential to cause harm, under extended shifts schedule compared with reduced work hours/week. It was found that residents working extended shifts had more polysomnographic-recorded attentional failures during work hours[17]; nevertheless, the trial was not large enough to determine whether shift duration affects attention in a way that increases the risk for adverse event occurrence. In a larger study of U.S. residents, Barger et al[18] reported a positive association between extended shifts and attentional failures, ME, and adverse events. However, data relied on self-reports not independently validated.

Cognitive function may be the linking factor between schedule-related fatigue and potential ME. Evidence suggests that fatigue, sleep duration, and low alertness has a role in modifying cognitive function (e.g., working memory, attention, and behavioral performance).[6,19–21] Specifically, vigilant attention is impaired by sleep deprivation and restored after rest breaks and more so after sleep.[22] Moreover, sleep disorders are manifested in the performance on the Test of Variables of Attention (TOVA), suitable for evaluating speed and accuracy[23] of sustained attention based on processing speed,[24] vigilance, and impulsivity.[25] For example, TOVA scores are in the abnormal range in 63%[26] of patients with sleep apnea syndrome; also, children with both sleep apnea and attention-deficit/hyperactivity disorder (ADHD) were found to suffer from worse[27] performance on the TOVA preadenotonsillectomy. The TOVA response time (RT) was significantly worse in patients with both ADHD and sleep disorders than those without them.[28] Furthermore, a delayed circadian rhythm disorder is prevalent in more than 70%[29,30] of both children and adults with attention disorder. In view of that, fatigue and sleep deprivation are exhibited as attention impairment and vice versa.

We aim to further investigate the adverse effects of workload fatigue on physicians' attention functioning by the valid traditionally used TOVA. Assuming that ME occurs on the account of attention failures, we aim to provide an objective attention evaluation in a large sample of hospital residents from different residencies following sleep deprivation due to work overload. Interestingly, a recent study intended to provide a national database of the prevalence burnout among physicians surveyed more than a thousand physicians from different residency programs to find that burnout was high across all fields, with gynecology and internal medicine at the top and psychiatry at the bottom.[31] Nevertheless, only the administrators of the programs were evaluated, and the inventory lacked validity for the study population. Accordingly, we aim (1) to test if induced fatigue (24-hour shift) is manifested in attention performance and (2) to compare attention performance according to the field of residency. Thus, we hypothesize that a sleep deprivation due to workload

From the *Department of Occupational Therapy, Faculty of Social Welfare and Health Sciences, University of Haifa, Haifa, Israel; †Department of Psychiatry, Geha Mental Health Center, Petah Tikva, Israel; and ‡Emek Medical Center, Afula, Israel.

Correspondence: Avi Avital, PhD, Behavioral Neurobiology Lab, Department of Occupational Therapy, Faculty of Social Welfare and Health Sciences, University of Haifa, 199 Aba Khoushy Ave, Haifa, Israel (e-mail: Avitalavi@hotmail.com).

D.T., Z.S. are equal contributors.

This study was partially supported by The Legacy Heritage Foundation (11-2012, awarded to A.A.).

All authors disclose no conflict of interest.

The study was approved by the local institutional review board.

will impair the physicians' attention in association with their residency field.

METHODS

Subjects

The study was conducted in the Emek Medical Center (Afula, Israel) and approved by the local institutional review board. Data were collected anonymously and to fulfill the institutional review board's requirements. The study included 109 residents sampled randomly and equally among males and females. Participants belonged to the following medical residency fields: internal medicine, gynecology, anesthesia, surgery, ICU, or psychiatry. Note that the ICU residents were in a full-time ICU residency.

Exclusion criteria were as follows: diagnosed ADHD or sleep disorder, active psychiatric or neurological disease, pregnancy, time spent within 1 month in a destination with more than 2 hours of time zone difference, and regular use of sedative, stimulant, anxiolytic, and/or antidepressant medications. Diagnoses were based on self-reports.

Procedure

Residents were tested twice using the TOVA right before they started a 24-hour shift (8:00 AM) and right at the end of their shift (8:00 AM on the next day). The shift content differed across the residency fields, as follows: the internal medicine residents treat 10 to 12 patients in the ward, mostly for infections, pneumonia, urinary infection, heart failure, myocardial infection, and acute renal failure. Anamnesis and physical check take ~1 hour per patient (including documentation). The gynecology residents treat about 13 patients in women's emergency department in addition to the patients they have in the delivery rooms and in the ward. They are responsible for the emergency checks (~20 minutes each), vacuum extractions, and surgical procedures (cesarean delivery, exams under full anesthesia, and internal bleeding), which take ~1 hour each. The anesthesia residents treat an extremely high number of patients and work mostly in operating rooms with no rest periods at all. There are 1 attending physician and 2 on-call residents with a variety of responsibilities such as epidural injections, insertion of complex zondas, shock room care, and even chaperoning head trauma patients to get treatment in different hospitals as well as help with other emergency cases that occur on their way back. The surgery residents are working 3 per shift, one in the emergency department that treats 50 to 100 cases including trauma and abdominal pain, another one in the ward that treats 20 to 40 cases including patients before and after operation, and one more who performs about 5 surgical procedures of bowel obstruction, exploratory laparotomy, abscess, and appendectomy, which take 1 to 3 hours each. The ICU residents treat about 20 patients (who are mostly hospitalized) while spending ~3 hours for severe cases (trauma, car accidents, sepsis, cardiac events, snake bites) versus 2 hours for mild cases (abdominal pain, urinary infection, minor bruises). They juggle between patients while waiting to receive their laboratory and imaging results. Finally, the psychiatry residents treat 8 to 10 patients, ~1 hour per patient, including 2 cases of involuntary/voluntary hospitalizations, 2 cases of suicide attempts, and 1 to 2 cases of psychosis and addictions. They also give counseling in the pediatric ward for children with anxiety attacks, suicidal alerts, and behavioral disorders.

Caffeine and nicotine were not allowed at least 1 hour before testing. All subjects reported normal sleep duration the night before the study and a normal shift workload. Consumption of caffeine (cups) and nicotine (cigarettes) was monitored to address possible confounding effects.[32] Residents were asked to record any significant resting periods (sitting/lying down).

Test of Variables of Attention

We used V8.0 TOVA normalized by age and sex. In a 20-minute session, a flashing large square is presented for 100 milliseconds with a 2-second intertrial interval. Target and nontarget stimuli are defined as the appearance of a small box on the top or bottom of the large square, respectively. Subjects were instructed to press a microswitch every time the target appears and to avoid pressing every time a nontarget appears. Accordingly, the following variables were evaluated:

RT: time required pressing the microswitch after presented with the target, that is, the processing time taken to respond correctly. Persons with ADHD may respond slower.[23]

RT variability: consistency level of RTs, that is, the standard deviation of correct response times. Individuals with ADHD tend to have inconsistent RT and thus have a wider RT variability. This is considered the most sensitive measure for attention deficit.[23,33]

D-prime: ability of perceptual sensitivity to discriminate between target and nontarget stimuli (i.e., the ratio of hit rate to false alarm rate). Most individuals tend to experience fatigue over time; yet, with ADHD, the performance tends to deteriorate faster.[23]

Omissions: a measure of focus and vigilance and occur when the subject omits clicking the microswitch in response to a target stimulus presented; this may be due to inattention, distractibility, or hyperactivity. Omission errors are rare in adults.[23]

Commissions: a hallmark of ADHD that measures impulsivity and occur when the subject incorrectly clicks the microswitch in response to the nontarget stimulus presented. Generally, at the individual level, excessive commission errors decrease omission errors, shorten RTs, and increase variability; therefore, it is an important measure of test validity.[23]

Attention comparison score: It measures overall attention performance, which compares the performance with individuals who have been independently diagnosed with ADHD.[23]

Scores are presented as standard scores (SSs) and categorized as follows: SSs >110 are above average, SSs of 85 to 110 are average, SSs of 80–85 are considered borderline; and SSs <80 are not within normal limits. For attention comparison score, score <0 was considered below the normal range.

Statistical Analysis

Variables were first tested for normal distribution using skewness and kurtosis statistics. A 2-way analysis of variance for mixed design with residency fields as between-subject factor and test time as within-subject factor was performed. One-way analysis of variance followed by post hoc Tukey tests was used to compare differences between residencies. A paired-sample t test was used to compare performance at baseline and after a 24-hour shift. Associations between variables were calculated using Pearson correlation coefficient. The statistical tests were conducted using Bonferroni-adjusted α levels, and results were considered significant if P value <0.05. Results are displayed as mean ± SEM, unless otherwise specified.

RESULTS

Demographics, Sleep Duration, and Nicotine and Caffeine Intake

As expected, age was negatively correlated with attention performance. The variables found to be moderately correlated with age were as follows: omissions at baseline and after 24 hours (r_{63} = −0.495, −0.499; P < 0.000); commissions at baseline and after 24 hours (r_{63} = −0.399, P < 0.001; r_{63} = −0.523, P < 0.000); D-prime at baseline (r_{63} = −0.438, P < 0.000); and attention comparison score at baseline (r_{63} = −0.402, P < 0.001). The variables found to be weakly correlated with age were as follows: RT at baseline and after 24 hours (r_{63} = −0.365, P < 0.003; r_{63} = −0.362, P < 0.004); D-prime after 24 hours (r_{63} = −0.302, P > 0.016); and attention comparison score after 24 hours (r_{63} = −0.248, P < 0.050). Merely RT variability, the variable most sensitive to attention deficit, did not correlate with age.

All residents had rested for no more than 45 minutes; rest time did not correlate with any of the examined attention variables. The anesthesia residents rested for significantly longer time compared with all other residents ($F_{5,108}$ = 7.216, P < 0.001; η^2 = 0.259).

Caffeine was tested for covariance and was found to have no effect over the attention variables. Internal medicine residents consumed most cups, whereas psychiatry residents consumed the least number of cups ($F_{5,108}$ = 7.439, P < 0.001; η^2 = 0.265).

Cigarette smoking was not normally distributed and thus described by median and range (Table 1).

TOVA Variables

To quantify the extent of impairment, we calculated the frequency of subjects with borderline-impaired scores, based on SS <80. At baseline, although 37% of physicians had SS not within the normal range in omissions, 14% in attention comparison score, 13% in D-prime, and 6% in RT variability; all of them had normal baseline SS in commissions and RT. After 24 hours, the impaired performance percent increased in all the variables but commissions and RT, which remained within the normal range among all physicians. The impairment percent change was most pronounced in attention comparison score (+20%) and RT variability (+16%) after 24 hours (Table 2).

Results revealed a significant deterioration after the shift across all variables (P < 0.001), as demonstrated by the aforementioned increasing percentage of subjects with impaired performance. Notably in most variables, the decline in performance was not merely statistical but clinical as it reached the verge of borderline-abnormal spectrum (RT variability and D-prime, attention comparison score, and omissions, respectively; Table 3). Surprisingly, 8 of all physicians were found to have abnormal baseline performance in at least 3 variables. Because ADHD diagnosis cannot be made solely based on TOVA, henceforth, these subjects are referred to as the "ADHD-like group."

TOVA Variables Across Residency Fields

Omission

The ICU had the worst baseline SS (internal medicine and psychiatry, P < 0.0001; gynecology, P < 0.001; anesthesia, P < 0.013; surgery, P < 0.042). Psychiatry remained with significantly better SS than surgery (P < 0.006) and ICU (P < 0.017) after 24 hours. Post hoc analysis revealed impairment among internal medicine (P < 0.0001), gynecology (P < 0.001), anesthesia (P < 0.0001), surgery (P < 0.016), and psychiatry (P < 0.0001), but no effect for the ICU, which showed a tendency of improvement within the abnormal range (Fig. 1A).

Commission

Psychiatry had the best baseline SS (internal medicine, P < 0.01; gynecology, anesthesia, and ICU, P < 0.0001; surgery, P < 0.008) and the lowest decline rate after 24 hours, and had significantly better SS than gynecology (P < 0.002) and ICU (P < 0.001). Furthermore, anesthesia had the greatest SS decline and significantly lower SS than internal medicine (P < 0.001), surgery (P < 0.011), and psychiatry (P < 0.0001). Post hoc analysis revealed impairment among all residencies (P < 0.0001), including the ICU (P < 0.01; Fig. 1B).

Response Time

Psychiatry exhibited the best baseline SS (i.e., shorter RT) compared with ICU (P < 0.019) as well as after 24 hours compared with all residencies (internal medicine, surgery, and ICU, P < 0.0001; gynecology, P < 0.035; anesthesia, P < 0.016). Post hoc analysis revealed impairment among internal medicine (P < 0.002), gynecology (P < 0.0001), anesthesia (P < 0.0001), and surgery (P < 0.001), but not psychiatry and ICU (Fig. 1C).

RT Variability

Surgery and psychiatry baseline SSs were higher compared with internal medicine (P < 0.0001, P < 0.003), gynecology (P < 0.001, P < 0.035), anesthesia (P < 0.0001, P < 0.008), and ICU (P < 0.001, P < 0.043). Post hoc analysis revealed a significant impairment among all residencies (internal medicine, P < 0.0001; gynecology, P < 0.0001; anesthesia, P < 0.0001; surgery, P < 0.0001; psychiatry, P < 0.008; and ICU, P < 0.0001). However, after 24 hours, surgery, ICU, and psychiatry scored within the normal range compared with internal medicine (P < 0.011) and anesthesia (P < 0.015) whose performances were below the normal range. Psychiatry had significantly better

TABLE 1. Demographics, Rest Duration, and Nicotine and Caffeine Intake

	Residency Fields						
	Internal (n = 31)	Gynecology (n = 16)	Anesthesia (n = 16)	Surgery (n = 16)	ICU (n = 16)	Psychiatry (n = 14)	Total (N = 109)
Age, y	32.54 ± 6.44	33.85 ± 3.23	39.71 ± 7.54	35.25 ± 4.78	41.4 ± 9.71	33.66 ± 6.20	34.52 ± 6.91
Relative percentage, %	28.44	14.67	14.67	14.67	14.67	12.84	100
Rest duration (min)	9.67 ± 14.17	6.25 ± 9.74	21.25* ± 8.42	10.5 ± 10.00	0	9.28 ± 8.51	9.52 ± 11.70
Nicotine consumption, no. cigarettes	0.64 ± 1.56	1.06 ± 2.23	1.43 ± 2.09	0	0.62 ± 1.25	0	0.64 ± 1.56
Caffeine consumption, no. cups	5.93* ± 4.01	4.56 ± 2.50	3.12 ± 1.99	2.93 ± 1.34	5.81 ± 4.23	0.78 ± 1.25	4.2 ± 3.46

Data are presented as average ± SD. Nicotine and caffeine consumptions are presented as median (range).

* P < 0.05.

TABLE 2. TOVA Variable Impairment Before and After a Shift Across Residency Fields

		Residency Fields							
		Internal (n = 31)	Gynecology (n = 16)	Anesthesia (n = 16)	Surgery (n = 16)	ICU (n = 16)	Psychiatry (n = 14)	Total (N = 109)	%
Omission rate	Baseline	7	4	7	9	13	0	40	36.7
	Post 24 h	12	7	8	13	6	0	46	42.2
Commission rate	Baseline	0	0	0	0	0	0	0	0.0
	Post 24 h	0	0	0	0	0	0	0	0.0
RT	Baseline	0	0	0	0	0	0	0	0.0
	Post 24 h	0	0	0	0	0	0	0	0.0
RT variability	Baseline	6	0	0	0	0	0	6	5.5
	Post 24 h	12	5	6	0	0	0	23	21.1
D-prime	Baseline	4	1	0	1	8	0	14	12.8
	Post 24 h	10	1	0	6	5	0	22	20.2
Attention comparison score	Baseline	7	3	0	1	4	0	15	13.8
	Post 24 h	14	6	6	6	5	0	37	33.9

The number of physicians who performed not within the normal range before and after a 24-hour shift across the TOVA variables. All variables, but RT and CO, increased after 24 hours, with the RT variability and attention comparison score being most affected. Impairment was considered as any SS <80 (<0 for attention comparison score). Data are presented using frequency and percent.

SS than internal medicine, gynecology, anesthesia ($P < 0.0001$), and ICU ($P < 0.022$; Fig. 1D).

D-Prime

The ICU had the lowest baseline SS compared with internal medicine ($P < 0.004$), anesthesia ($P < 0.008$), and psychiatry ($P < 0.0001$). After 24 hours, Psychiatry values were higher than internal medicine ($P < 0.001$), surgery ($P < 0.014$), and ICU ($P < 0.014$). Post hoc analysis discovered impairment among internal medicine ($P < 0.0001$), gynecology ($P < 0.0001$), anesthesia ($P < 0.0001$), surgery ($P < 0.002$), and psychiatry ($P < 0.0001$), but not ICU ($P > 0.714$; Fig. 1E).

Attention Comparison Score

The ICU had the lowest baseline score compared with surgery ($P < 0.008$) and psychiatry ($P < 0.0001$) whose scores were below the normal range, and psychiatry had the highest score compared with ICU ($P < 0.0001$) and internal medicine ($P < 0.046$). After 24 hours, psychiatry remained with the highest score compared with all other residencies ($P < 0.001$) and was the only residency that remained within the normal range. Post hoc analysis exposed a significant impairment among internal medicine ($P < 0.0001$), gynecology ($P < 0.0001$), anesthesia ($P < 0.0001$), surgery ($P < 0.0001$), and psychiatry ($P < 0.003$), but not ICU ($P > 0.443$; Fig. 1F).

TABLE 3. TOVA Variables Before and After a Shift

Variables (SS)	Baseline	Post 24 h	*P*
Omission rate	85.53 ± 20.30	**78.88** ± 20.06	0.0001
Commission rate	113.96 ± 5.61	108.81 ± 7.14	0.0001
RT	115.62 ± 6.06	113.53 ± 7.09	0.0001
RT variability	101.44 ± 4.01	89.59 ± 13.48	0.0001
D-prime	99.25 ± 15.26	89.19 ± 15.51	0.0001
Attention comparison score	0.82 ± 2.96	**−1.35** ± 2.74	0.0001

The scores of all the TOVA variables significantly decreased after 24 hours. Impairment was considered as any variable with SS <85 (<0 for attention comparison score) and accentuated in bold. Data are presented as average ± SD.

In summary, excluding the ICU, a significant decrease was observed in omissions ($F_{1,103}$ = 18.300, $P < 0.001$), D-prime ($F_{1,103}$ = 50.5, $P < 0.001$), and attention comparison score ($F_{1,103}$ = 127.803, $P < 0.001$). Excluding the ICU and psychiatry, a significant reduction was detected in RT ($F_{1,103}$ = 18.429, $P < 0.001$). All residencies decreased their commissions ($F_{1,103}$ = 211.363, $P < 0.001$) and RT variability ($F_{1,103}$ = 208.528, $P < 0.001$), with merely surgery, ICU, and psychiatry residents scored within the normal range. Notably, the ICU had an abnormal baseline to begin with (Fig. 1).

ADHD-Like Group

A small group of 8 physicians (7.34%) shared impaired baseline performance, defined as SS <85 in at least 3 variables, compared with the rest who performed in the normal range across all variables. The group had abnormal values in omissions-SS, D-prime–SS, and attention comparison score and included 2 ICU, 1 surgery, and 5 internal medicine residents. Interestingly, this group was less affected by lack of sleep compared with residents within the normal range, and significantly deteriorated only in RT variability ($P < 0.001$), which is considered the most sensitive for attention deficit.[33] The normal baseline group significantly deteriorated in all SSs ($P < 0.0001$; Table 4).

DISCUSSION

The study's main aim was to objectively evaluate the effects of sleep deprivation due to work overload on attention performance in a large sample of residents. The TOVA results confirmed the adverse effects of work overload–induced fatigue on visual attention functioning. The impact of a 24-hour shift was most pronounced, to varying degrees, in some of the TOVA variables (e.g., the attention comparison score, RT variability, and D-prime), while being inconsistent in others (e.g., RT and commissions). Specifically, the attention comparison score declined to abnormal range, and the RT variability and D-prime dropped to borderline scores. Accordingly, the increased numbers of subjects with impaired

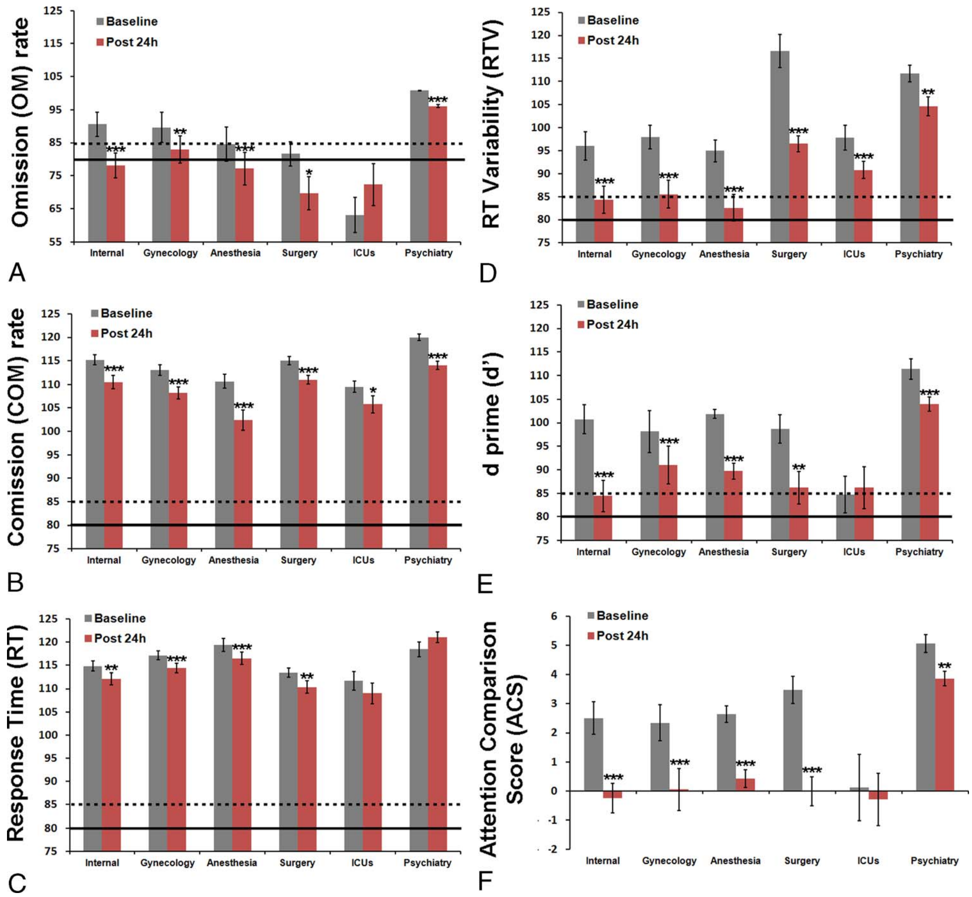

FIGURE 1. Variables of TOVA before and after a shift across residency fields. A–F, Valued in SSs. B and D, CO-SS and RTV-SS significantly decreased in all residencies. A, E, and F, OM-SS, D-prime–SS, and ACS significantly decreased in all residencies but the ICU. C, RT-SS significantly decreased in all residencies but the ICU and psychiatry. The decrease in RTV-SS, OM-SS, D-prime–SS, and ACS exceeded the normal range for some residencies. Data are presented as average ± SD; SSs of 80–85 are considered borderline, and SSs <80 are not within normal limits (<0 for ACS). **P* < 0.05, ***P* < 0.01, ****P* < 0.001. ACS, attention comparison score; CO, commissions; OM, omissions; RTV, RT variability.

performance were highest in those variables (25% in RT variability, 20% in attention comparison score, and 15% in D-prime). Notably, the borderline omission score at baseline switched to abnormal values after the shift. This deterioration profile observed among the residents carries clinical implications, as it was seen in all variables, excluding RT and commissions, thus indicating deficient

TABLE 4. ADHD-Like Group Versus the Normal Performance Group Across TOVA Parameters

	Variables (SS)	Baseline	Post 24 h	*P*
Normal baseline	Omission rate	88.12 ± 18.63	**80.84** ± 18.97	0.0001
	Commission rate	114.08 ± 5.30	108.77 ± 6.87	0.0001
	RT	115.94 ± 5.82	113.66 ± 6.86	0.0001
	RT variability	101.63 ± 14.58	89.77 ± 13.58	0.0001
	D-prime	101.25 ± 13.50	90.24 ± 14.89	0.0001
	Attention comparison score	0.96 ± 2.84	**−1.33** ± 2.79	0.0001
ADHD-like group	Omission rate	**52.88** ± 9.31	**54.13** ± 17.71	0.859
	Commission rate	112.5 ± 9.05	109.25 ± 10.66	0.084
	RT	111.63 ± 7.99	111.88 ± 9.99	0.929
	RT variability	99 ± 16.80	87.25 ± 12.75	0.001
	D-prime	**74** ± 14.16	**76** ± 18.19	0.597
	Attention comparison score	**−0.89** ± 4.02	**−1.59** ± 2.20 ±	0.575

The ADHD-like group decreased significantly merely in the RT variability after 24 hours. Impairment was considered as any variable with SS <85 (<0 for attention comparison score) and accentuated in bold. Data are presented as average ± SD.

attention functioning characterized by inattentiveness and lack of perceptual sensitivity but preserved processing speed and inhibition control (i.e., impulsivity) after an extended shift.[23] Previous studies showed deterioration in psychomotor vigilance performance tasks[34] and in recall memory and concentration[35] after an extended shift. In accordance, residents made significantly less momentous errors during an intervention schedule that eliminated extended work shifts.[16] Longer sleep deprivation induced by a 36-hour on-call shift negatively affected obstetrical resident physicians' cognitive performance as manifested in all the TOVA variables.[36]

Our second aim was to test for differences in attention performance across various residencies. We found that the extended shift led to a differential degree of attentional failure as a function of the residency field. After a night shift, residents from all fields, excluding psychiatry, exhibited circumstantial ADHD-like symptomology, which resembled a profile of individuals with attention disorder. Accordingly, although, after their shift, psychiatrists remained within the normal range, residents from other fields showed pathological impairment in at least 2 variables, indicating clinical differences between the residency fields. For example, the psychiatrist is situated in a designated room and the patients approaches this room; thus, the psychiatrist is required to have less physical movement compared with all other residencies.

Generally, there are 2 types of errors: omissions occurring as a result of actions not taken (inattentiveness) versus commissions occurring as a result of the wrong action taken (impulsivity). After their shift, internal medicine, gynecology, and surgery residents tended to behave as those suffering from "ADHD predominantly inattentive," as their impaired functions were inattention and processing speed, but not inhibition. Furthermore, the scores of the internal medicine, anesthesia, and gynecology did not merely decline but crossed to the abnormal range of the RT variability, which is a stable feature of attention disorder.[37] Clinically, it could mean that these residents are not more impulsive at the end of their shift, but rather act slower and less attentive, which could lead to severe preventable ME, for example, slower information processing when the response speed time is urgent like in poisoning, severe allergic reactions, or massive bleeding.

Interestingly, the residential variances were similar at baseline and after a shift, indicating that the shift load affected the residents differentially and not as a group; the psychiatry performed best, whereas the ICU presented a borderline-abnormal performance, compared with all other fields. Nevertheless, in some of the TOVA variables, the ICU effects were not statistically recognized (RT, omissions, D-prime, and attention comparison score). Those who had abnormal baseline performance (specifically among the ICU, internal medicine, and surgery), referred to as the "ADHD-like group," were less affected by lack of sleep, as they demonstrated a decrease only in one variable (RT variability), considered the most sensitive measure of attention deficit[33]; meanwhile, the normal baseline group deteriorated in all variables. Therefore, this group is prone to make ME, starting with knowledge transfer when shift changes and ending with misdiagnoses: for example, more than 28% of autopsies reporting at least 1 misdiagnosis and 8% identifying a class I diagnostic error leading to as many as 40,500 adult ICU patients in the United States who may die with a misdiagnoses annually.[38] In general, advancing societal age and increasing population growth rate accompanied by disproportionally financial investment are a strain on healthcare systems and specifically on surgeries[39] and may lead not only to severe adverse events but also to approximately one-quarter of preventable readmissions.[40]

The ADHD-prone subjects being less affected may explain that the ICU had the lowest baseline performance but was also the only group who changed only in 1 variable. A possible explanation is the increased existence of sleep disorders together with ADHD,[41] especially delayed sleep disorder and a tendency of day and night reversal. Thus, ADHD-prone personnel may be less susceptible to the negative effect of shift duration. If so, the results also demonstrate the diminished effect of external sleep disorder given a prior attention deficit, and a question is raised whether the choice of a specific residency field rather than the others is also related to this specific characteristic (e.g., specializing in ICU or surgery over gynecology or psychiatry).

Taking into consideration that all residents reported not to have ADHD, a doubt regarding their diagnosis might arise along with the need for residency programs to improve screening and ongoing monitoring procedure of potential residents as a preventive act. The latter is important in light of a burnout issue that has gained increasing attention among the medical community. For instance, it is estimated that 30% to 50% of all physicians experience burnout or burnout-symptoms.[42,43] Symptoms of burnout appear as early as medical school and place medical students at higher risk of depression and suicidal ideation.[44] Thus, another possible explanation to discuss regarding the unexpected ICU baseline performance is the burnout resulting from the highly stressful occupational nature of the field.[45] A single episode of stress can lead to a long-lasting hormonal alteration[46]; so stress exposure chronicity is expected to take its toll and may prevent bouncing back to normal baseline performance as observed in the ICU field. Moreover, adults with higher stress levels also report on decreased sleep duration,[47] hence being less affected by lack of sleep.

Finally, the lack of sleep effects can be counted as an additional wakefulness state that has a neurobiological cost accumulating over time[48]; therefore, differences in residential training overload and demands can explain why one field may present better or worse baseline attention skills compared with the others. For instance, psychiatry residents consumed the lowest amount of caffeine and exhibited the best attention performance, which may emphasize a specific residential field profile. As expected, supporting subjective data indicated physicians from the psychiatry field are less burned out compared with other residency fields.[31] Another possibility is that functional capabilities may affect the choice of residency to begin with. For example, psychiatrists may be viewed with better attention skills owing to the use of communication as their principle tool of professional practice. Differently, ICU may be viewed with attention dysfunction as a group, featured by high tension and high adrenaline load as required when taking care of multiple urgent events while examining many imaging and serological findings simultaneously.

CONCLUSIONS AND RECOMMENDATIONS

Physicians' baseline performance indicated a tendency for attention deficit among them, characterized by low alertness and inattentiveness but preserved inhibition control. This kind of attention profile is much more outwardly indistinguishable and may explain why none of them reported any dysfunction when they entered the study. Furthermore, based on the literature linking attention failures to ME, the distinct deficits among physicians working long shifts while assigned to treat patients add up to a growing body of research emphasizing the need for intervention and improved regulations to cope with the possible consequences, such as ME and associated hazards.[49] Pending more research, our findings also support incorporating residency training practices into future guidelines (e.g., shorter shifts for ICU residents), to advance public health by minimizing potential for ME occurrence. Also, interventions for targeting burnout factors such as sleep problems during residency years hold promise for improving patient care and safety. The consequences of burnout including personal factors such as stress and depression are shared by impaired attention and thus have organizational impacts like decreased quality of care, increased clinical errors, reduced empathy for patients, decreased patient satisfaction, and higher turnover rates, with some physicians leaving practice altogether.[43]

LIMITATIONS AND FUTURE RESEARCH

No direct data regarding ME made in the previous work period were collected and quantified as part of the present study; thus, we cannot state how the attention data relate directly and causatively to ME. Furthermore, specific shift characteristics of each residency were not monitored and quantified, so their contribution to attention performance failure cannot be established. Thus, further research is needed to specify the shifts' content, which mostly affects attention performance in each residency field.

Note that the results of the ADHD-like subgroup lack validity for the inadequate number of physicians comprising this group. However, the existence of residency-related ADHD-prone personnel highlights the need for further research to establish if a connection between the choice of residency and attention characteristics exists. Residency programs might also benefit from future research and knowledge on how to screen better and vet residents before and during residency years. Finally, additional research is needed to elucidate whether the negative effect of shift duration on attention lessens when baseline attention is already impaired, thus highlighting the limited sensitivity of evaluation methods such as the TOVA.

ACKNOWLEDGMENT

The authors thank Dr Avital Gaziel and Miss Anna Grossman for her assistance in editing the manuscript.

REFERENCES

1. Iglehart JK. Revisiting duty-hour limits—IOM recommendations for patient safety and resident education. *N Engl J Med*. 2008;359:2633–2635.
2. Kohn LT, Corrigan JM, Donaldson MS, eds. *No Title*. Washington, DC; 2000. doi:10.17226/9728.
3. Sunshine JE, Meo N, Kassebaum NJ, et al. Association of adverse effects of medical treatment with mortality in the United States: a secondary analysis of the Global Burden of Diseases, Injuries, and Risk Factors Study. *JAMA Netw Open*. 2019;2:e187041.
4. Kavanagh KT, Saman DM, Bartel R, et al. Estimating hospital-related deaths due to medical error: a perspective from patient advocates. *J Patient Saf*. 2017;13:1–5.
5. Makary MA, Daniel M. Medical error—the third leading cause of death in the US. *BMJ*. 2016;353:i2139.
6. Panagioti M, Khan K, Keers RN, et al. Prevalence, severity, and nature of preventable patient harm across medical care settings: systematic review and meta-analysis. *BMJ*. 2019;366:l4185. doi:10.1136/bmj.l4185.
7. de Vries EN, Ramrattan MA, Smorenburg SM, et al. The incidence and nature of in-hospital adverse events: a systematic review. *Qual Saf Health Care*. 2008;17:216–223.
8. Jha AK, Larizgoitia I, Audera-Lopez C, et al. The global burden of unsafe medical care: analytic modelling of observational studies. *BMJ Qual Saf*. 2013;22:809–815.
9. Harris JD, Staheli G, LeClere L, et al. What effects have resident work-hour changes had on education, quality of life, and safety? A systematic review. *Clin Orthop Relat Res*. 2015;473:1600–1608.
10. Laine C, Goldman L, Soukup JR, et al. The impact of a regulation restricting medical house staff working hours on the quality of patient care. *JAMA*. 1993;269:374–378.
11. Petersen LA, Brennan TA, O'Neil AC, et al. Does housestaff discontinuity of care increase the risk for preventable adverse events? *Ann Intern Med*. 1994;121:866–872.
12. Alsafi E, Bahroon SA, Tamim H, et al. Physicians' attitudes toward reporting medical errors—an observational study at a general hospital in Saudi Arabia. *J Patient Saf*. 2011;7:144–147.
13. Anderson B, Stumpf PG, Schulkin J. Medical error reporting, patient safety, and the physician. *J Patient Saf*. 2009;5:176–179. doi:10.1097/PTS.0b013e3181b320b0.
14. Harrison R, Lawton R, Perlo J, et al. Emotion and coping in the aftermath of medical error: a cross-country exploration. *J Patient Saf*. 2015;11:28–35.
15. McCormick F, Kadzielski J, Evans BT, et al. Fatigue optimization scheduling in graduate medical education: reducing fatigue and improving patient safety. *J Grad Med Educ*. 2013;5:107–111.
16. Landrigan CP, Rothschild JM, Cronin JW, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med*. 2004;351:1838–1848.
17. Lockley SW, Cronin JW, Evans EE, et al. Effect of reducing interns' weekly work hours on sleep and attentional failures. *N Engl J Med*. 2004;351:1829–1837.
18. Barger LK, Ayas NT, Cade BE, et al. Impact of extended-duration shifts on medical errors, adverse events, and attentional failures. *PLoS Med*. 2006;3:e487.
19. Walker MP, Stickgold R. Sleep, memory, and plasticity. *Annu Rev Psychol*. 2006;57:139–166.
20. van der Linden D, Massar SA, Schellekens AF, et al. Disrupted sensorimotor gating due to mental fatigue: preliminary evidence. *Int J Psychophysiol*. 2006;62:168–174.
21. Kendall AP, Kautz MA, Russo MB, et al. Effects of sleep deprivation on lateral visual attention. *Int J Neurosci*. 2006;116:1125–1138.
22. Hudson AN, Van Dongen HPA, Honn KA. Sleep deprivation, vigilant attention, and brain function: a review. *Neuropsychopharmacology*. 2020;45:21–30.
23. Greenberg LM, Holder C, Carol Kindschi LL, Tammy Dupuy MR. The TOVA Company. 2020. Available at: http://www.tovatest.com/. Accessed January 31, 2021.
24. Braverman ER, Chen TJH, Schoolfield J, et al. Delayed P300 latency correlates with abnormal Test of Variables of Attention (TOVA) in adults and predicts early cognitive decline in a clinical setting. *Adv Ther*. 2006;23:582–600.
25. Braverman ER, Chen AL, Chen TJ, et al. Test of Variables of Attention (TOVA) as a predictor of early attention complaints, an antecedent to dementia. *Neuropsychiatr Dis Treat*. 2010;6:681–690.
26. Avior G, Fishman G, Leor A, et al. The effect of tonsillectomy and adenoidectomy on inattention and impulsivity as measured by the Test of Variables of Attention (TOVA) in children with obstructive sleep apnea syndrome. *Otolaryngol Head Neck Surg*. 2004;131:367–371.
27. Huang Y-S, Guilleminault C, Li H-Y, et al. Attention-deficit/hyperactivity disorder with obstructive sleep apnea: a treatment outcome study. *Sleep Med*. 2007;8:18–30.
28. Huang Y-S, Chen N-H, Li H-Y, et al. Sleep disorders in Taiwanese children with attention deficit/hyperactivity disorder. *J Sleep Res*. 2004;13:269–277.
29. Craig SG, Weiss MD, Hudec KL, et al. The functional impact of sleep disorders in children with ADHD. *J Atten Disord*. 2020;24:499–508.
30. Van Veen MM, Kooij JJ, Boonstra AM, et al. Delayed circadian rhythm in adults with attention-deficit/hyperactivity disorder and chronic sleep-onset insomnia. *Biol Psychiatry*. 2010;67:1091–1096.
31. Ewen AM, Higgins MCSS, Palma S, et al. Residency and fellowship program administrator burnout: measuring its magnitude. *J Grad Med Educ*. 2019;11:402–409.

32. Swerdlow NR, Eastvold A, Gerbranda T, et al. Effects of caffeine on sensorimotor gating of the startle reflex in normal control subjects: impact of caffeine intake and withdrawal. *Psychopharmacology (Berl)*. 2000;151: 368–378.
33. Epstein JN, Erkanli A, Conners CK, et al. Relations between continuous performance test performance measures and ADHD behaviors. *J Abnorm Child Psychol*. 2003;31:543–554.
34. Gander P, Millar M, Webster C, et al. Sleep loss and performance of anaesthesia trainees and specialists. *Chronobiol Int*. 2008;25:1077–1091.
35. Qureshi AU, Ali AS, Hafeez A, et al. The effect of consecutive extended duty hours on the cognitive and behavioural performance of paediatric medicine residents. *J Pak Med Assoc*. 2010;60:644–649.
36. Andreyka K, Tell P. An analysis of continuous performance test scores before and after sleep deprivation in obstetrical resident physicians. Available at: https://academic.oup.com/acn/article/11/5/362/1664. Accessed January 31, 2021.
37. Kofler MJ, Rapport MD, Sarver DE, et al. Reaction time variability in ADHD: a meta-analytic review of 319 studies. *Clin Psychol Rev*. 2013;33: 795–811.
38. Custer JW, Galvagno SM, Winters B, et al. Diagnostic errors in the intensive care unit: a systematic review of autopsy studies article. *BMJ Qual Saf*. 2012;21:894–902.
39. Patel R, Ashcroft J, Darzi A, et al. Neuroenhancement in surgeons: benefits, risks and ethical dilemmas. Available at: https://academic.oup.com/bjs/article-abstract/107/8/946/6094437. Accessed June 23, 2021.
40. Auerbach AD, Kripalani S, Vasilevskis EE, et al. Preventability and causes of readmissions in a national cohort of general medicine patients. *JAMA Intern Med*. 2016;176:484–493.
41. Walters AS, Silvestri R, Zucconi M, et al. Review of the possible relationship and hypothetical links between attention deficit hyperactivity disorder (ADHD) and the simple sleep related movement disorders, parasomnias, hypersomnias, and circadian rhythm disorders. *J Clin Sleep Med*. 2008;4:591–600.
42. West CP, Dyrbye LN, Shanafelt TD. Physician burnout: contributors, consequences and solutions. *J Intern Med*. 2018;283:516–529.
43. Gabbay RA, Barrett AM. Endocrinologist burnout: we need to tackle it and bring joy to work. *J Clin Endocrinol Metab*. 2020;105:dgaa230.
44. Rotenstein LS, Ramos MA, Torre M, et al. Prevalence of depression, depressive symptoms, and suicidal ideation among medical students a systematic review and meta-analysis. *JAMA*. 2016;316:2214–2236.
45. Reader TW, Cuthbertson BH, Decruyenaere J. Burnout in the ICU: potential consequences for staff and patient well-being. *Intensive Care Med*. 2008;34:4–6.
46. Greetfeld M, Schmidt MV, Ganea K, et al. A single episode of restraint stress regulates central corticotrophin-releasing hormone receptor expression and binding in specific areas of the mouse brain. *J Neuroendocrinol*. 2009;21:473–480.
47. Stress and sleep. Available at: https://www.apa.org/news/press/releases/stress/2013/sleep. Accessed June 23, 2021.
48. Van Dongen HP, Maislin G, Mullington JM, et al. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*. 2003;26:117–126.
49. Barger LK, Cade BE, Ayas NT, et al. Extended work shifts and the risk of motor vehicle crashes among interns. *N Engl J Med*. 2005;352: 125–134.