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Measurement of resident fatigue using rapid number naming

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ABSTRACT

Objective: Sleep deprivation has a negative effect on neurocognitive performance. The King-Devick test (KDT), which tests speed and accuracy of number-reading, requires integrity of saccades, visual processing, and cognition. This study investigated effects of sleep deprivation in on-call residents using KDT.
Methods: A prospective cohort study was conducted among 80 residents. KDT was performed at the beginning and end of an overnight call shift for the residents in the experimental group. A control group was tested at the beginning of 2 consecutive day shifts. Estimates of hours of sleep, Karolinska Sleepiness Scale (KSS)(1 = extremely alert, 9 = extremely sleepy), and time and accuracy of KDT were recorded.
Results: 42 residents were tested before and after overnight call shifts and 38 served as controls. Change in test time differed between the groups, with the experimental group performing 0.54(SD = 4.0) seconds slower after their night on call and the control group performing 2.32(SD = 3.0) seconds faster on the second day, $p < 0.001$. This difference was larger in surgical compared to medical residents.
Conclusions: Sleep deprivation was inversely correlated with neurocognitive performance as measured by KDT, with more effect on surgical than medical residents. Further research could investigate whether this test could help determine fatigue level and ability to continue working after a long shift.

1. Introduction

Sleep deprivation is an important issue in residency training. Work hour regulations for interns and residents result from a desire to maximize patient safety and resident well-being while providing sound post-graduate education. The Accreditation Council for Graduate Medical Education recently increased the maximum resident work hours, allowing first-year residents to do 28-h shifts: 24 h of call duty and 4 h for transition [1].

Sleep deprivation has been found to negatively impact neurocognitive performance, particularly noted in psychomotor and cognitive speed, vigilance, executive attention, working memory, and higher cognitive abilities [2]. Cognitive performance has been shown to decrease by almost one standard deviation with sleep deprivation, slightly less in physicians compared to the general population [3]. One study compared the state of being on call to alcohol consumption and found that during a heavy call rotation, residents displayed neuro-behavioral impairment comparable to those with a blood alcohol concentration of 0.04–0.05%. Residents had limited judgment of their degree of impairment [4].

While sleep-related neurocognitive dysfunction traditionally has been assessed using extensive neuropsychological testing, tablet-based tasks and post-concussion testing have more recently been used [5–7]. One such post-concussion test is the King-Devick test (KDT) (King

Abbreviations: KDT, King-Devick Test; KSS, Karolinska Sleepiness Scale; PGY, Post-graduate year

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Devick Test, Inc., Oakbrook Terrace, IL), which tests speed and accuracy of rapid number-naming and requires saccadic integrity, visual processing, cognition, speech, and language [8–12]. Especially relevant to our project, it requires intact saccadic eye movements which, in turn, require a fully-functioning system of cortical structures working in tandem such as frontal eye fields and the dorsolateral prefrontal cortex. These may be prone to disruption and dysfunction from head trauma [12] and perhaps, sleep deprivation. Given these neurocognitive underpinnings, the KDT has been found to be a rapid and sensitive diagnostic screen of cognitive impairment following concussion in athletes [9] and in other traumatic brain injuries [13,14]. The test typically has a learning effect, with subjects improving their speed from baseline testing. Davies et al. [15] used the KDT to study the effects of sleep deprivation on neurology residents and demonstrated less improvement in speed from baseline testing in on-call residents compared to control residents who were not on call.

The aim of this study was to use the KDT to evaluate the effects of sleep deprivation on resident performance, and assess differences between residents of different services in a large academic medical center.

2. Methods

2.1. Study approval

This study was approved by the Institutional Review Board of Albert Einstein College of Medicine and was conducted in accordance with the tenets of the Declaration of Helsinki, 2013. Participation was voluntary and signed informed consent was obtained from all residents prior to participation.

2.2. Setting and participants

We conducted a prospective, observational study among residents in post-graduate years (PGY) 1–4 at a large urban teaching hospital in Bronx, NY. Residents from anesthesiology, otorhinolaryngology, internal medicine, neurology, ophthalmology, and pediatrics were placed into two groups: the experimental group taking overnight call and the control group which was not taking overnight call. A power calculation was performed to determine the sample size using the findings of a previous study by Davies et al. [15]. The improvement in KDT time was expected to be 4 s faster from baseline to subsequent testing, with a standard deviation of 4 s. To have at least an 80% statistical power to detect a difference between the experimental and control groups, we determined sample sizes of 20 residents per group. In case the difference between the groups was smaller, we aimed for 50 per group. We also aimed for a 50:50 distribution between medical (internal medicine, neurology, and pediatrics) and surgical services (anesthesiology, otorhinolaryngology and ophthalmology). All screenings, consent, questionnaire administration, and testing were conducted by a single investigator (MED). Exclusion criteria were near visual acuity (uncorrected or with the participants' typical correction) worse than 20/40 or a history of traumatic brain injury.

2.3. Study design

The test was performed with KDT software using an Apple iPad Pro (Apple Inc., California, USA). The KDT measures the speed and accuracy of rapid number naming. The task involves reading aloud numbers presented on three cards from left to right in which the numbers get closer together and more difficult to read (Fig. 1). Following a tutorial, participants are told to read the cards as quickly as possible without making an error and to continue reading even in the event of an error. The test is done twice and the faster time score plus the number of errors are recorded.

For the experimental group, the test was performed prior to beginning overnight call, followed by testing at the end of the shift. The control group was tested at the beginning of two consecutive non-call days.

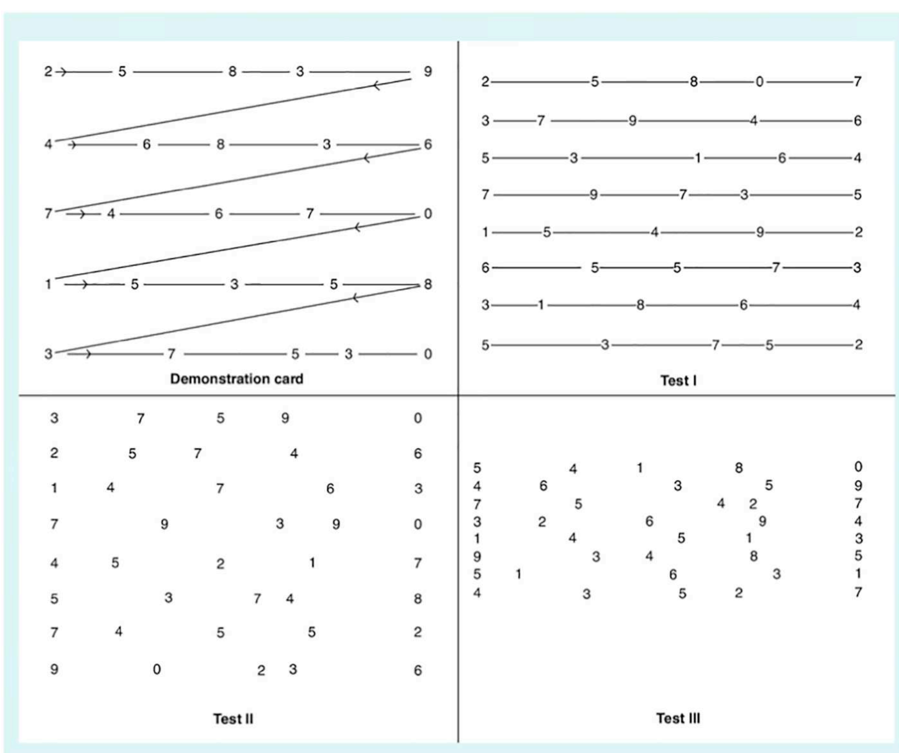

Fig. 1. Example of the King-Devick Test.
King-Devick Test® (K-D Test®)©2018. Disclaimer: King-Devick Test images above are not to scale and for illustration purposes only.

2.4. Sleepiness questionnaire

The Karolinska Sleepiness Scale (KSS), a frequently used scale for assessing overall tiredness, was obtained. Residents were asked how much sleep they got the previous night, 24-h period, and preceding week, and to determine how sleepy they felt using a 9-point scale, from 1 (extremely alert) to 9 (extremely sleepy, fighting sleep).

2.5. Measurements

The primary outcome measure was the difference between the two time scores for each resident. Accuracy was also compared. Demographic data including age, gender, PGY, KDT scores and errors, hours of sleep prior to both testing sessions, KSS and time since their last caffeine intake were tabulated on an Excel spreadsheet.

2.6. Statistical analysis

All statistical calculations were performed using SAS software (Statistical Analysis Software, SAS institute Inc. Cary, NC, USA). Continuous variables were described with mean, median and standard deviations (SD) and categorical variables with percentages. Comparisons of KDT scores and errors between residents on call and those not on-call were performed using chi-square or two-sample *t*-tests. Linear regression analysis was used to assess KDT performance comparisons between groups, adjusting for potential confounding factors. Pearson's correlation test was used to test the significance of associations between the differences in baseline and post-test KDT scores and the variables collected by the questionnaire (e.g. age, gender, PGY, hours of sleep, KSS, and medical service). Statistical significance was set at p-value < 0.05.

3. Results

3.1. Demographics

Forty-two experimental group residents were tested before and after overnight call shifts and thirty-eight served as controls. Mean age and gender breakdown were similar between groups. The experimental group completed significantly more post-graduate years than the control group. (Table 1).

3.2. Reported duration of sleep prior to testing

There were no significant differences in hours slept over the past week or the past twenty-four hours between the experimental and control residents. The control group slept fewer hours than the experimental group the night prior to the pre-test, but as expected, they slept significantly more hours than the experimental group the night before and in the 24-h period before the post-test. (Table 2).

3.3. Reported feelings of sleepiness at the time of testing

KSS scores were similar at the time of the pre-test between the groups. The experimental group residents did report significantly greater feelings of sleepiness than controls at the time of the post-test. (Table 2) Of note, there was too much variability in the way caffeine intake was reported to analyze this variable.

3.4. Changes in King-Devick test score, pre- to post-test: all residents

Change in KDT score from pre- to post-test differed significantly between groups: the experimental group performed slower following their night on call (0.54 +/− 3.99 s), while the control group performed faster than their pre-test (−2.32 +/− 2.99 s) ($p < 0.001$) (Table 3). This difference remained significant after adjustment for hours of sleep the night before the pre-test ($p = 0.018$) and for pre-test KDT scores ($p = 0.004$). Adjusting for both variables together, there was a trend toward greater KDT score improvements for residents in the control group ($p = 0.052$). This trend remained even after adjusting for both variables and PGY differences simultaneously ($p = 0.069$).

Higher scores on the sleepiness scale prior to the pre-test were associated with more KDT score improvement in the post-test (Pearson $r = -0.28$, $p = 0.013$). In contrast, higher scores on the sleepiness scale in the post-test were associated with a worsening of the KDT score (Pearson $r = 0.22$, $p = 0.045$) (Fig. 2). When the experimental and control groups were separated, there was no correlation between post-call KSS and improvement in KDT score (experimental Pearson $r = 0.056$, $p = 0.723$; control Pearson $r = -0.094$, $p = 0.575$) (Fig. 3).

3.5. Number of KDT errors

During both the pre-test and the post-test, there was no significant difference in number of errors made by the experimental residents and

Table 1
Demographics of Experimental and Control Residents.

Characteristic	Residents on call ($N = 42$)	Residents not on call ($N = 38$)	P value
Mean Age in years (SD)	28.95 (2.49)	29.84 (3.36)	0.179
Mean Gender, number female (%)	20 (47.6)	18 (47.4)	0.982
Mean PGY Year (SD)	2.71 (0.71)	2.21 (1.21)	0.029

PGY = post-graduate year, SD = standard deviation.

Table 2
Estimated Hours of Sleep and Karolinska Sleepiness Scale Scores.

Characteristic	Residents on call ($N = 42$)	Residents not on call ($N = 38$)	P value
Mean Sleep Week Before Pre-test [hours, (SD)]	44.65 (5.81)	44.50 (8.83)	0.927
Mean Sleep 24 Hours Before Pre-test [hours, (SD)]	8.23 (2.31)	7.88 (3.31)	0.595
Mean Sleep Night Before Pre-test [hours, (SD)]	7.27 (1.21)	6.01 (1.34)	< 0.001
Mean Sleep Week Before Post-test [hours, (SD)]	43.64 (7.19)	45.07 (8.82)	0.430
Mean Sleep in 24 Hours Before Post-test [hours, (SD)]	3.17 (2.16)	6.76 (1.39)	< 0.001
Mean Sleep Night Before Post-test [hours, (SD)]	2.91 (1.84)	6.54 (1.22)	< 0.001
Mean KSS Score at Pre-test [score, (SD)]	3.33 (1.69)	3.89 (1.89)	0.164
Mean KSS Score at Post-test [score, (SD)]	5.93 (1.72)	3.50 (1.57)	< 0.001

KSS = Karolinska Sleepiness Score, SD = standard deviation.

Table 3
Score and Number of Errors on King-Devick Test.

Characteristic	Residents on call (*N* = 42)	Residents not on call (*N* = 38)	P value
Mean baseline KDT score, seconds (SD) Pre-test	40.02 (5.73)	43.88 (7.57)	0.012
Mean KDT score, seconds (SD) Post-test	40.56 (6.66)	41.56 (6.94)	0.515
Mean Change in KDT score Pre-test to Post-test, seconds (SD)	0.54 (3.99)	−2.32 (2.99)	< 0.001
Mean Errors (SD) Pre-test	0.43 (0.80)	0.74 (0.89)	0.107
Mean Errors (SD) Post-test	0.29 (0.51)	0.58 (1.03)	0.118

SD = standard deviation.

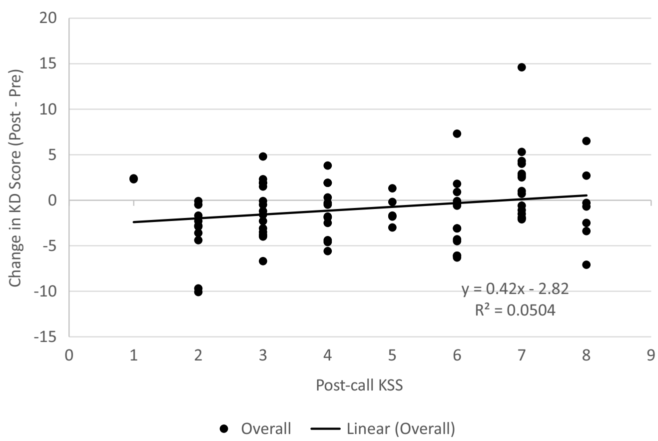

Fig. 2. The Association between change in King-Devick score and post-call Karolinska Sleepiness Scale scores.

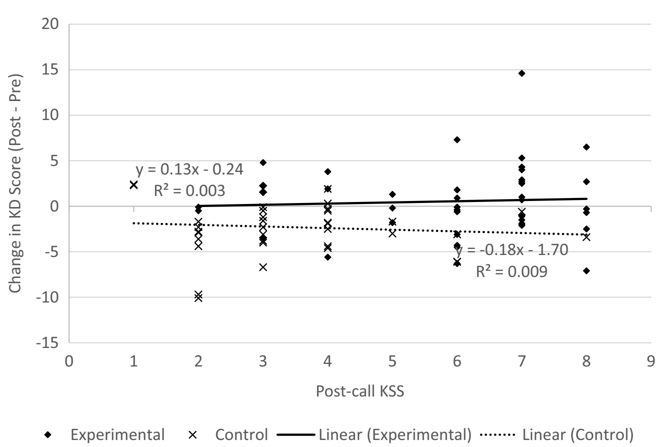

Fig. 3. The Association between change in King-Devick score and post-call Karolinska Sleepiness Scale score for experimental and control groups.

the control residents. (Table 3).

3.6. *Difference in KDT score changes between surgical and medical service specialties*

The subjects were analyzed in groups of surgical (anesthesiology, otorhinolaryngology and ophthalmology) and medical services (internal medicine, neurology, and pediatrics). The groups had similar relationships between hours of sleep and KSS score (Fig. 4).

Surgical residents in the experimental group had less improvement in KDT score time, slowing down on the post-test (1.11 +/− 3.90 s) versus their control group counterparts who became faster (−2.22 +/− 1.84 s) ($p < 0.001$). In contrast, medical residents in the experimental group did not differ significantly in KDT score improvement

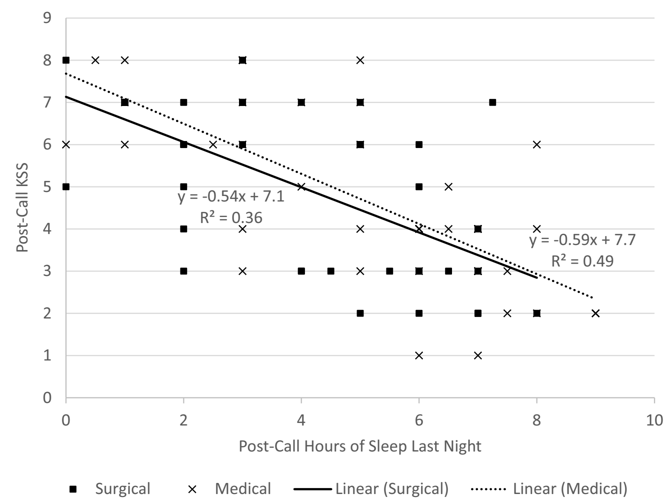

Fig. 4. The association between Karolinska Sleepiness Scale scores and hours of sleep for surgical and medical residents.

(−0.6 +/− 4.06 s) from their control group counterparts (−2.37 +/− 3.42 s) ($p = 0.152$) (Table 4).

4. Discussion

Most residents are episodically sleep-deprived. Earlier studies of medical residents have shown relationships between sleep deprivation and quality of life, burnout and depression [16], empathy [16], sleepiness and fatigue [17], cognitive and motor performance [17–19], likelihood of motor vehicle accidents [20], and medical errors [21,22]. Collectively, these studies highlight the extensive negative effects of sleep deprivation on residents. There is currently no point-of-care testing used to directly measure fatigue and its associated effects on functioning.

Our study used the KDT to test neurocognitive function following call duty. In individuals in the control group, we expected an improvement in scores on post-test KDT scores compared to pre-test scores based on a learning effect of repeated exposure to the task, and a comparatively diminished improvement in score or worse score in those from the experimental group taking call [11]. Our main findings affirmed the results of Davies et al. [15], demonstrating that the KDT is an effective metric for detecting changes in neurocognitive function.

The fact that the on-call residents did not improve their time on the KDT may have implications for learning during overnight shifts, whether applied to procedural skills or cognitive knowledge. Encouragingly, there was no significant difference in the error rates, which may indicate that residents have some awareness of the need to slow their speed to not make errors when fatigued.

We noted that the on-call residents had faster pre-test scores as well as higher reported hours of sleep prior to the night of call. These residents may have prepared for their call shifts by sleeping more the night before. Alternatively, the control group may have been recovering from a recent call. When we accounted for both difference in the pre-

Table 4
Change in Medicine and Surgery Resident Scores.

Characteristic	Residents on call	Residents not on call	P value
Medicine Residents Mean Change in KD score from Pre to Post-test, seconds (SD)	−0.6 (4.06), $N = 14$	−2.37 (3.42), $N = 26$	0.152
Surgery Residents Mean Change in KD score from Pre to Post-test, seconds (SD)	1.11 (3.90), $N = 28$	−2.22 (1.84), $N = 12$	< 0.001

SD = Standard deviation.

test scores and the hours of sleep, the change in KDT score from pre-to post-test continued to trend strongly toward statistical significance, with the call group exhibiting less improvement in KDT scores.

Interestingly, when the groups were separated into medical and surgical fields, residents from the surgical fields maintained a statistically significant difference between their pre- and post-test scores for the on-call and not-on-call groups while the medical residents did not. This difference may represent a variance in physical and mental engagement required while on call or how busy the residents were during the call night. This discrepancy between services contributes to our current knowledge of KDT testing in residents. Further research is required to confirm this difference and to elucidate causative factors, as well as to determine how adjusting the circadian rhythm with a night float system would influence the findings.

There were several limitations of our study that could have introduced bias to the results. Although the groups were similar in age and gender, we used a convenience sample of residents based on their call schedule instead of randomizing them. Also, post-graduate year level was significantly different, likely because at the time of testing, first-year residents were not doing 24-h calls at our facility. Blinding of the groups was also not possible because the residents knew whether they were on call or not and the coordinator was required to use this information to locate the residents at the appropriate time. In addition, we did not analyze the substances that that the residents took the evening before testing or during the 24-h period, such as alcohol or caffeine, which could have accounted for differences in wakefulness/arousal while performing the test. Lastly, our power calculations for the sample size required were based on a prior study [15] and are therefore contingent on the veracity of that study.

Despite these limitations, our study showed that residents' improvement on a repeat KDT varied significantly based on whether they were on call between testing sessions or not. Thus, sleep deprivation in residents is correlated with neurocognitive compromise as measured by KDT.

5. Conclusion

Residents' cognitive function can be evaluated by the King-Devick test, a test that broadly assesses neurocognitive status and afferent/efferent vision and which has been used as a screening tool for certain impairments. While there are exciting new developments in tools that specifically track the visual system and eye movements such as video-oculography [23], the KDT nevertheless shows tremendous promise as a comparatively quick and convenient proxy for one's general neurocognitive status. Further research, possibly including further details about sleep characteristics and substance use, could establish a role for KDT in assessing resident fatigue and capacity to function following long on-call shifts.

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Conflict of interest

The authors declare no conflicts of interest.

Data statement

Data is available for review upon request.

Prior poster presentation

This data was presented at the 2018 Annual Meeting of the North American Neuro-ophthalmology Society.

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