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Sleep deprivation increases cognitive workload during simulated surgical tasks

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Abstract

BACKGROUND: There have been conflicting reports of the effects of modest sleep deprivation on surgical skills. The aim of this study was to assess the effects of a 24-hour call shift on technical and cognitive function, as well as the ability to learning a new skill.

METHODS: Thirty-one students trained to expert proficiency on a virtual reality part-task trainer. They then were randomized to either a control or sleep-deprived group. On the second testing day they were given a novel task. Fatigue was assessed using the Epworth Sleepiness Scale. The National Aeronautics and Space Administration–Task Load Index was used to assess cognitive capabilities.

RESULTS: There was no difference between the control and sleep-deprived groups for performance or learning of surgical tasks. Subjectively, the Epworth Sleepiness Scale showed an increase in sleepiness. The National Aeronautics and Space Administration–Task Load Index showed an increase in total subjective mental workload for the sleep-deprived group.

CONCLUSIONS: Sleep-deprived subjects were able to complete the tasks despite the increased workload, and were able to learn a new task proficiently, despite an increase in sleepiness.
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Simulation has gained increasing significance in the medical field as reports cite its ability to reduce costs (including the cost of medical training), help eliminate errors, and improve patient safety continue to be published.[1] Particularly in surgery, simulation has become the introduction to many procedures for new residents. Coupled with the 80-hour work-week restriction, simulation is becoming increasingly important to ensure an adequate level of skill before surgery on a patient.[1,2]

There have been several studies published using simulators to determine the effects of sleep deprivation on surgical skill. No consensus has been reached within these studies as to how surgical skills are affected.

Uchal et al[3] compared the ability of 32 attending-level surgeons to suture a simulated perforated ulcer on a foam stomach and found that sleep deprivation had no impact on surgical task performance. Similarly, Jakubowicz et al[4] assessed the performance of 8 general surgery residents on the novice mode of an endoscopic sinus surgery simulator before and after a 24-hour call period. They, too, found no diminutions in surgical task performance. Lehmann et al[5] found no difference in medium-term tasks in a sleep-deprived group.

Interestingly, these reports conflict with the results of sleep disruption on nonmedical simulated tasks. The ability to fly a plane,[6] operate a locomotive,[7] and drive an automobile[8,9] all are affected significantly by sleep deprivation.

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Two such studies showed impairment in simulated performance equivalent to moderate blood alcohol levels.[7,8]

However, Kahol et al[10] compared surgical residents in a precall and postcall condition and found a significant increase in cognitive errors when they looked at memory, attention, and intermodal coordination. Several other studies have found similar results relating to dexterity,[11] anesthetist performance,[9] and laparoscopic skills on night shifts.[12]

Cognitive workload is an important yet often unrecognized component of performance. Workload has been described as a hypothetical construct that represents the cost incurred by the human operator to achieve a particular level of performance.[13] More demanding tasks incur a higher cognitive workload, leaving less spare capacity to deal with new or unexpected events, such as a bleeding vessel or other such intraoperative complications.[14] Increased errors have been seen as a result of increased workload.[14,15] Similarly, Montero et al[16] found a higher workload was associated with a poorer performance in laparoscopic surgery. Other investigators have tried to identify potential ways to reduce surgeon workload in an attempt to decrease surgical risk and increase effective communication for patient safety.[17]

Time estimation via an internal clock has been studied previously in the literature. The internal clock is essential for driving a car, or for walking across a busy street.[18] It has been shown that sleep deprivation affects time estimation, and changes to the internal clock can greatly affect mental workload.[19]

Clearly then, the question remains as to whether and to what degree medical psychomotor skills are affected by sleep deprivation.[20] The answers to these questions are important because they impact not only patient safety, but also the cost of health care.[21] From a training perspective, sleep deprivation may affect resident skill acquisition and their ability to retain surgical skills. Because Accreditation Council for Graduate Medical Education regulations at this time stipulate that residents average no more than 80 hours of work per week, with more significant changes on the horizon,[22] residents must be able to acquire and retain surgical experience in less time than ever before.

Little attention in the literature is devoted to understanding how modest sleep deprivation impacts both task performance and concurrent mental workload. Our aim was to assess laparoscopic task performance and perceived mental workload in a control and sleep-deprived condition. We theorized that laparoscopic performance would suffer, that mental workload would increase, and that learning a new skill would be harder in the sleep-deprived condition. Our study focused on laparoscopic simulation and assessment of mental workload as assessed by the National Aeronautics and Space Administration–Task Load Index (NASA-TLX) scale.

Methods

Study design

This was a randomized prospective trial comparing 2 groups of medical students, one sleep-deprived group and one control group. Baseline testing was performed on day 1, and then repeated on day 2, with the subjects either fully rested (control) or sleep deprived.

Study population

After Institutional Review Board approval of the study, subjects were selected based on open enrollment from the third- and fourth-year medical student classes at Penn State Hershey Medical Center. After informed consent was obtained, the subjects were randomized based on enrollment to either the control group or the sleep-deprived group before training and testing.

Outcome measures

The Epworth Sleepiness Scale. At the start of both testing days the subjects were asked to complete a survey, the Epworth Sleepiness Scale (ESS), designed to evaluate measures of daytime sleepiness.[23] The ESS is a subjective assessment of daytime sleepiness. The range of this test is from 0 to 24, with 24 being the highest measure of daytime sleepiness. Although no formal rating scale is assigned, with a score of 10 or greater it is recommended to seek the care of a physician. This test generally is used for sleep deprivation caused by sleep disorders, and is not generally used for acute sleep loss. However, the results have been shown to correlate daytime sleepiness with sleep loss as caused by sleep apnea.[23] An ESS score greater than 11.5 correlates to moderate daytime sleepiness, and a score greater than 16 correlates to severe daytime sleepiness as seen by the effects of severe sleep apnea.[23]

RapidFire simulator. RapidFire (Verefi Technologies, Elizabethtown, PA) was used to test subjects on the performance of learned, repetitive tasks. This simulator is a minimally invasive surgical trainer-virtual reality (MIST-VR)–like simulator, and has been studied in this capacity.[24] The basic RapidFire training levels are designed to teach hand-eye coordination and fulcrum effect motor skills related to laparoscopic surgery. Level one consists of acquiring (touching) smaller targets within larger targets with virtual laparoscopic instruments. Level 2 consists of acquiring a smaller target with one hand. Level 3 consists of acquiring the target with 2 hands simultaneously. The score is based on the number of targets acquired, efficiency of movement, and errors such as past pointing and tool collision. Time to completion of each level was set at 2 minutes.

EndoTower simulator. EndoTower (Verefi Technologies, Elizabethtown, PA), a validated VR trainer for angled endoscopic navigation,[25] trains subjects to manipulate a 30°, angled laparoscopic lens in simulated 3-dimensional space. The goal of the simulator is to identify the location of 6 target arrows within the EndoTower program by manipulating a simulated angled laparoscopic lens/camera assembly around a complex 3-dimensional object. A computerized error score was calculated as previously described.[26] Briefly, the total score is cal-

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