Effects of Sleep Hours and Fatigue on Performance in Laparoscopic Surgery Simulators

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"Running Head: Effects of sleep hours on surgical performance"

ABSTRACT

Background. Studies on a virtual reality simulator have demonstrated that sleep-deprived residents make more errors. Work-hour restrictions were implemented, among other reasons, to ensure enough sleep time for residents. The objective of this study was to assess the effects of sleep time, perceived fatigue, and experience on surgical performance. We hypothesized that performance would decrease with less sleep and fatigue, and that experienced surgeons would perform better than less experienced surgeons despite sleep deprivation and fatigue.

Methods. Twenty-two surgical residents and attendings performed a peg transfer task on two simulators: the Fundamentals of Laparoscopic Skills (FLS) trainer and the Virtual Basic Laparoscopic Surgical Trainer (VBLaST©), a virtual version of the FLS. Participants also completed questionnaires to assess their fatigue level and recent sleep hours. Each subject performed 10 trials on each simulator in a counterbalanced order. Performance was measured using the FLS normalized scores, and analyzed using a multiple regression model.

Results. The multiple regression analysis showed that sleep hours and perceived fatigue were not covariates. No correlation was found between experience level and sleep hours or fatigue. Sleep hours and fatigue did not appear to affect performance. Expertise level was the only significant determinant of performance in both FLS and VBLaST©.

Conclusions. Restricting resident work-hours was expected to result in less fatigue and better clinical performance. In our study, peg transfer task performance was not affected by sleep hours. Experience level was a significant indicator of performance. Further examination of the complex relationship between sleep hour, fatigue, and clinical performance is needed to support the practice of work-hour restriction for surgical residents.

Key words: Simulation, Fatigue, Work-hour restrictions, performance

INTRODUCTION

Previous studies have demonstrated that residents who were sleep deprived when post call made more errors when performing on a virtual reality (MIST-VR) surgical simulator.[1] Today, work-hour restrictions assure enough sleep time for residents throughout the week. The regulation is the most strict for interns, who are limited to a maximum of 16 hours per shift in the 80-hour work-week, as opposed to the 28-hour per shift limit for all other residents. In this new context, the aim of this study was to assess the effects of sleep time, perceived fatigue, and experience on surgical performance.

We hypothesized that the surgical performance of residents would decrease with less sleep and with fatigue, whereas experienced surgeons would perform better than less experienced surgeons despite sleep deprivation and fatigue.

MATERIALS AND METHODS

Participants

Twenty-two (22) subjects (25-55 years old; 16 males, 6 females) with varied experience in surgery were recruited for this Institutional Review Board (IRB) approved study from a teaching hospital in the Boston area. There were 5 PGY1s, 5 PGY2s, 2 PGY3s, 3 PGY4s, 3 PGY5s, and 3 surgical fellows/attendings. One of the subjects was left-hand dominant, while all others were right-handed.

Apparatus

The Fundamentals of Laparoscopic Skills (FLS) trainer and its virtual equivalent, the Virtual Basic Laparoscopic Surgical Trainer (VBLaST©) (Figure 1) were used for this study to perform the peg transfer task. A peg board was placed in the center of the FLS box trainer with 12 pegs and six rings. The six rings were on the left side of the peg board at the start of each trial. The VBLaST© trainer consisted of a virtual reality simulation of the FLS pegs and

rings, and two laparoscopic graspers connected to two haptic devices to provide force feedback.

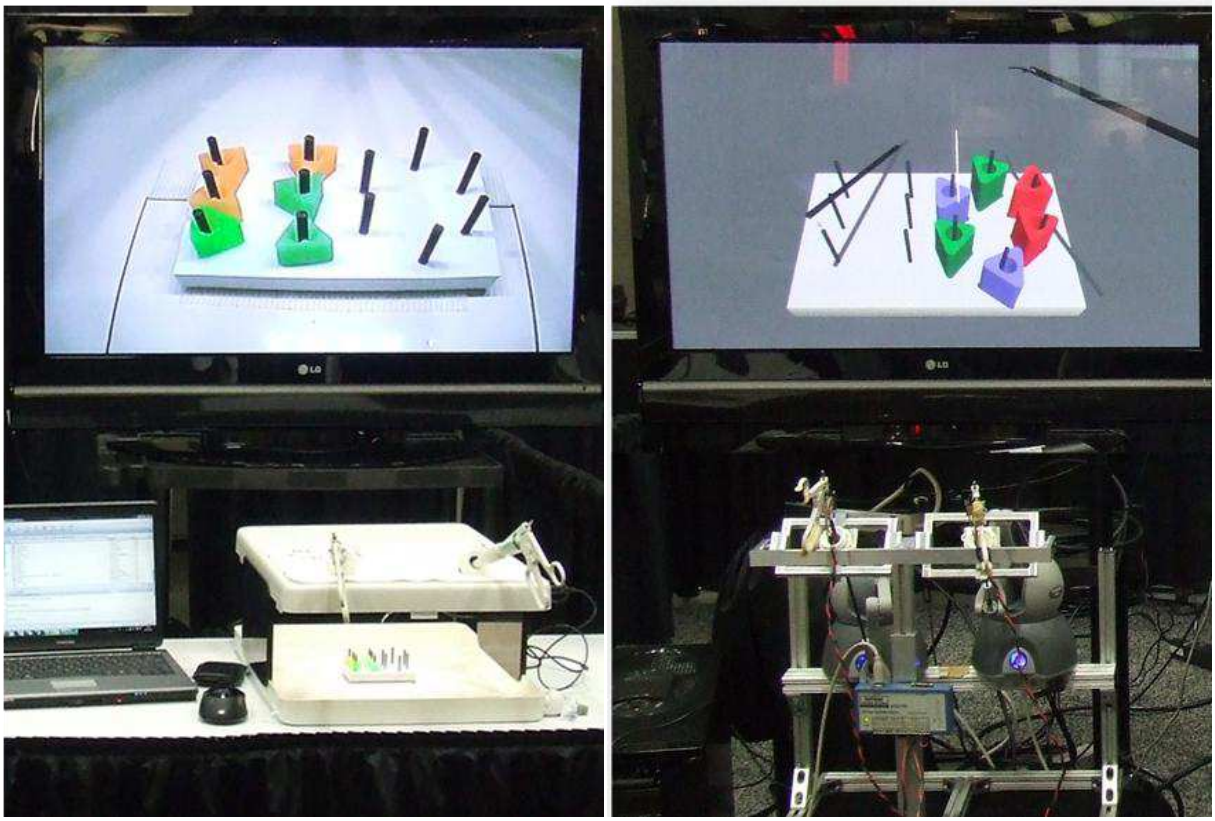


Fig. 1 The peg transfer task on two simulators: (Left) the FLS, (Right) the VBLaST©

Procedure

Before the start of the experimental session, subjects were asked to fill out a questionnaire detailing their laparoscopic surgery experience, their perceived fatigue level and their sleep hours.

The peg transfer task consisted of using two graspers (one in each hand) to pick up the rings (one at a time) with the non-dominant hand, transfer them to the dominant hand, and place them on the opposite side of the peg board. Once all the rings were transferred, the process was repeated to transfer the rings back to the other side of the peg board to complete one trial.

After watching an instructional video, each subject performed 10 trials of the peg transfer task on each simulator. The order of simulators was counterbalanced.

Dependent measures and data analysis

Subjects' performance on each simulator was measured for each trial based on the completion time and number of dropped pegs outside of the board. The task completion time and errors for the FLS trainer were recorded by one of the experimenters and a normalized numerical score was computed based on the proprietary scoring formula obtained from the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). For the VBLaST©, the score based on a similar formula, but with a different normalization factor, was calculated automatically by the software program at the end of each trial.

The expertise level (EL) for residents was determined by the post-graduate year (1 to 5 for PGY-1 to PGY-5, respectively), while level 6 was attributed to fellows and attendings. Participants self-reported their perceived fatigue level (FL) using a 5-point Likert scale (from (1) well rested to (5) really tired), and their sleep hours (SH) during the night preceding the test.

The multiple regression method was used to examine the relationship between the dependent variables (the FLS and VBLaST© peg transfer task performance scores) and the three independent variables (the expertise level, the perceived fatigue level, and the sleep hour). The Akaike Information Criterion (AIC) was used to choose the best-fit linear model. Moreover, the Spearman correlation test was used to estimate the coefficients of correlation between the different factors. All analyses were performed using "R", a free and open-source statistical analysis software.

RESULTS

The results from the questionnaire and the performance scores are summarized in Table 1.

Based on the individual data, 6 of the 22 subjects were "well rested". There was no significant difference in sleep hours or fatigue level across experience levels ($F_{(5,16)}=0.98$, $p>0.05$; $F_{(5,16)}=0.91$, $p>0.05$, respectively). No correlation was found between experience level and

Table 1: questionnaire answers and performance scores

	Min	Max	Mean	Standard deviation
Sleep Hours (SH)	4	8	5.59	1.08
Fatigue Level (FL)	2	4	2.88	0.65
FLS_{score}	55.40	100.00	87.02	11.98
$VBLaST_{score}$	14.48	91.74	66.07	21.21

sleep hours (r=0.16, p>0.05), between experience and fatigue level (r=-0.04, p>0.05), and between sleep hours and fatigue (r=-0.10, p>0.05). The multiple regression analysis showed that sleep hours and perceived fatigue were not covariates. The resulting linear models for performance on the two simulators are as follow:

$$FLS_{Score} = (90.13) - (4.70 * FL) + (3.33 * EL)$$

$$VBLaST_{Score} = (47.96) + (5.65 * EL)$$

The corresponding estimated factors coefficients are summarized in Table 2 for comparison.

Table 2: Multiple regression model coefficients

*** Significant values at P<0.05**	**FLS score**	**VBLaST© score**
Multiple R-squared (adjusted R-squared)	0.32 (0.26)	0.24 (0.20)
Intercept	90.13	47.96
Experience level (EL) Coefficient	**3.33***	**5.65***
Fatigue level (FL) Coefficient	-4.70	0
Sleep hour (SH) Coefficient	0	0

The results showed that sleep hours did not affect the performance. The perceived fatigue level affected the FLS performance with an inverse relationship but the effect was not statistically significant ($F_{(1, 20)}$= 1.84, p>0.05). Fatigue level had no effect on performance on the VBLaST©.

Finally, the expertise level showed a statistically significant effect on performance on both FLS and VBLaST© ($F_{(1, 20)}$=6.14, p=0.022 and $F_{(1, 20)}$=6.87, p=0.016, respectively), with a positive relationship. Post-hoc analyses showed that subjects with expertise level from 2-6 performed better than subjects with expertise level 1 on both simulators (Figure 2). There were no significant differences amongst the other experience levels.

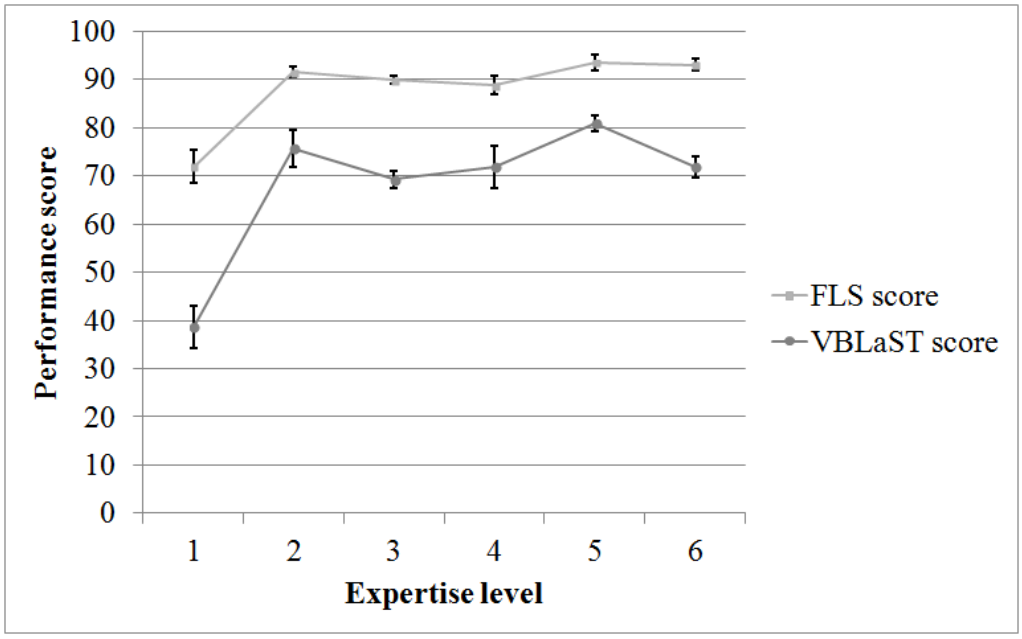


Fig. 2 The effect of experience levels on the performance scores

DISCUSSION

Poor sleep habit has been associated with worsened academic performance in medical students and higher rates of errors in medical intensive care unit residents.[2] Resident work hour restrictions were developed based on concerns regarding cognitive errors due to sleep deprivation in medical residents.[3] When these restrictions were implemented, the effect of sleeplessness on psychomotor performance was not well known.

The psychomotor vigilance test (PVT) is commonly used to test psychomotor skills during sleep studies, most of which are conducted on non-surgeons. In-Soo Lee et al. employed a PVT model to test subjects' reaction time to flashing red lights presented at variable time intervals.[4] They studied the effect of sleep deprivation on reaction time and

found a significantly slower reaction time in subjects reporting subjective fatigue. Although PVT testing involves psychomotor skills, these tasks are very basic compared to the most basic of surgical tasks. Participants doing PVT testing are often sitting down at a table, alone and with their arms rested on the table, thus encouraging a relaxed state. The test itself is a vigilance task (i.e., detecting intermittent and unpredictable signals over a long period of time) and thus prone to vigilance decrement (i.e., steep decline in performance after prolonged exposure). Some sleep-deprived participants may have stopped paying attention in this setting but perhaps would perform better with a less repetitive task, and/or while standing up. Surgeons in the operating room and on simulators are normally standing in close proximity to other people and constantly moving; therefore it is not appropriate to generalize the PVT test results to the operating room. This logic is supported by data collected on anesthesia residents comparing day to night shifts.[5] In addition to testing various cognitive tasks, a visual alarm based PVT was conducted with a red light on the anesthesia monitor that illuminated at random intervals. They found no difference in vigilance latency (alarm light response time) between the day and night shifts. A similar study compared the reaction time of sleep-deprived with well-rested anesthesiologists using three types of probes during a simulated laparoscopic surgery.[6] The first probe employed the classic PVT red light alarm at random intervals. The second probe was the sudden change to a flat-line waveform in the arterial line with no change in any other parameters (i.e., heart rate, manual blood pressure) thus simulating equipment failure. The third event was a change in vital signs over a 10-30 second time period, eventually resulting in a heart rate over 100 or blood pressure less than 70. There was a significant difference in performance on the third parameter, the more complex and clinically relevant event, but no difference on the simple isolated tests.

The inconsistent results with the PVT suggest that it may not be an adequate way of assessing alertness in clinical scenarios. The Imperial College Surgical Assessment Device (ICSAD) is a simulator that has been used as an alternative way to assess the effects of sleep

deprivation. One study using the ICSAD found significantly more errors and longer time to place an epidural in the sleep deprivation group. However, when stress level was included in the analysis, the two measures were no longer significant [7].

Based on the above, cognitive and psychomotor vigilance testing methods may not be the best way to measure the effect of sleep deprivation on surgical performance. Instead, any surgical performance changes due to sleep deprivation should be measured while performing the actual skills on a model, such as a physical laparoscopic trainer or a virtual reality system, or in the operating room. Studies conducted on physical trainers thus far have shown no difference in performance of skills despite sleep deprivation. Sleep deprivation data from virtual reality trainers have shown mixed results. In one study there was no difference in performance related to sleep deprivation in surgery residents both on a real trainer and on a virtual reality trainer.[8] Another study conducted on the MIST-VR trainer found that residents who were sleep deprived due to being post-call made more errors. However, the overall time and economy of motion were not altered.[**Erreur ! Signet non défini.**] The MIST-VR study did not test the skills on a real physical trainer. It is unclear whether the inconsistent outcomes are due to lack of a difference or lack of validity of the VR trainers.

In our study, resident and surgeon performance of the peg transfer task was measured on both a physical laparoscopic trainer and on a virtual reality trainer. We found that performance was not affected by hours of sleep the night before. There was a trend, though statistically not significant, towards poor performance on FLS with increased perceived fatigue level. Subjects with higher experience level performed better on the tasks than novices (PGY1), independent of sleep or fatigue level. However, our study was limited in that the cognitive aspect of peg transfer is much more simple than the procedures that have been studied in some of the previously mentioned studies. This study was performed on a very early iteration of the peg transfer task on our virtual reality simulator. While the

correlation in the results is promising, we are also developing newer versions of the previously validated VBLaST trainer [9].

It has been proposed that in surgery, residents develop skills that allow them to function well despite limited amounts of sleep. A meta-analysis of 16 studies conducted by Sturm et al. had completely mixed results with no overall conclusion regarding an effect of fatigue on clinical performance on simulators and actual patient outcomes.[10] In the studies that were included that showed worse resident performance with sleep deprivation, experience level was protective against this finding. The studies included in this meta-analysis that were retrospective reviews of actual patient outcomes found no difference.[11,12] Sharpe et al. studied the effects of attending surgeons working the day after a night on call and found no difference in the complication or readmission rates.[13] One study that tested the effects of sleep deprivation on physicians and non-physicians reported less variation in performance in the physician group, possibly because those test subjects were "used to" performing with little sleep.[14] Further, studies have shown adaptation to sleep deprivation after three nights, which would explain why experienced surgeons who are presumably adapted to sleeplessness did not show a difference in performance with acute sleep deprivation.[15] This finding does support the July 2011 addition to the ACGME duty-hours rules. In the 2011 update to the rules, residents in their final years of training are allowed to stay beyond the 80-work hours, or return to work in less than 8 hours, upon approval from their program director.[16] For a surgical resident, this may mean that a fourth- or fifth-year resident could stay beyond his/her maximal allowable hours to finish an uncommon case in the operating room. In addition, subjects in experience level 1 performed worse on both the virtual and real FLS than all other experience levels. Their poor performance more likely reflects lack of technical skills than any effect of sleep deprivation or fatigue. Although these were relatively basic tasks, in future studies perhaps novice data should be collected on even more simple skills, such as camera manipulation, or dominant-hand-only tasks.

In conclusion, in restricting work-hours for residents, the presumed increase in available sleep time is expected to lead to less chronic sleep deprivation, lower fatigue and better clinical performance. Our study shows that on both a physical trainer and on a virtual reality simulator, resident and surgeon performance of the peg transfer task was not affected by sleep hours. There was a trend towards worse performance on the FLS with fatigue. Perhaps taking into account the subjects' past three nights' sleep hours, as in other studies, we would have seen worse performance in sleep deprived residents as well.[15] In addition, with a larger number of subjects the fatigue group performance on FLS might have reached statistical significance. Further investigation is needed to provide evidence to examine the complex relationship between sleep, fatigue, and clinical performance in order to support the practice of work-hour restriction for surgical residents.

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Disclosures

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