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Effective home laparoscopic simulation training: a preliminary evaluation of an improved training paradigm

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Abstract

BACKGROUND: Laparoscopic simulation training has proven to be effective in developing skills but requires expensive equipment, is a challenge to integrate into a work-hour restricted surgical residency, and may use nonoptimal practice schedules. The purpose of this study was to evaluate the efficacy of laparoscopic skills training at home using inexpensive trainer boxes.

METHODS: Residents (n = 20, postgraduate years 1–5) enrolled in an institutional review board–approved laparoscopic skills training protocol. An instructional video was reviewed, and baseline testing was performed using the fundamentals of laparoscopic surgery (FLS) peg transfer and suturing tasks. Participants were randomized to home training with inexpensive, self-contained trainer boxes or to simulation center training using standard video trainers. Discretionary, goal-directed training of at least 1 hour per week was encouraged. A posttest and retention test were performed. Intragroup and intergroup comparisons as well as the relationship between the suture score and the total training sessions, the time in training, and attempts were studied.

RESULTS: Intragroup comparisons showed significant improvement from baseline to the posttest and the retention test. No differences were shown between the groups. The home-trained group practiced more, and the number of sessions correlated with suture retention score ($r^2 = .54, P < .039$).

CONCLUSIONS: Home training results in laparoscopic skill acquisition and retention. Training is performed in a more distributed manner and trends toward improved skill retention.

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Laparoscopic simulation training curricula have proven to be effective and efficient in developing skills that translate into improved operative performance,^{1–3} but these curricula require the use of expensive laparoscopic equipment based in simulation centers, are challenging to integrate into a surgery residency curriculum with work-hour restrictions,

and may use practice schedules that are not optimal for skill development and retention. Funding for simulation center development and equipment is becoming more challenging to obtain. Medical device companies have routinely underwritten the laparoscopic equipment in simulation centers.⁴ However, with the new AdvaMed Code of Ethics on Interactions with Healthcare Professionals,⁵ such donations are likely to decrease or cease, creating financial difficulty for new simulation centers to develop a program and for existing simulation centers to maintain current equipment. The development of more cost-effective training methods may be necessary.

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There has been a call for trainees to practice on their own time⁶ and for the training devices to be conveniently available, allowing trainees to practice more consistently and repetitively when it fits into their schedule.⁷ Training in a simulation center is rarely done on the trainees' own time because the time required in the simulation center setting is counted toward the 80-hour workweek, mandated by the Accreditation Council for Graduate Medical Education, as is the travel time to and from the center. Training is rarely set to easily fit the trainees' schedule and is more often set to fit into the simulation centers' and technicians' schedule. Using such a predetermined schedule for simulation requires the resident to cease patient care at that time and find appropriate patient care coverage, potentially creating patient-safety issues and handoff issues. A regimented schedule may also require the trainee to practice when stressed or fatigued. To minimize scheduling and fatigue issues, simulation centers set up voluntary training time. The perception of residents that voluntary training time in a simulation center is not convenient or efficient is indicated by their lack of interest in the optional use of simulation center training.^{7,8}

Additionally, practice schedules in simulation centers may not be optimal for skill development and retention. The most commonly used simulation practice timetable remains a once weekly schedule,⁴ often set up as time on a single task for the full session. Although better than massed practice, this schedule falls short on criteria of ample opportunities for repetition needed for deliberate practice⁹ and on the variability of tasks shown to enhance skill retention in nonmedical environments.¹⁰⁻¹⁴ The development of a method of training that would limit training time during periods of fatigue; allow for improvement in the distribution of practice, perhaps daily practice; and create training with variability or contextual interference may further the effectiveness of simulation.

The purpose of this study was to evaluate the efficacy of laparoscopic skills training at home using an inexpensive box trainer. Home training, using a box-trainer simulator with a web camera, will be compared with simulation center training using standard laparoscopic equipment, including a flat-panel liquid crystal display screen, xenon light source, and a high-definition laparoscopic camera. It is hypothesized that the home training will result in skill acquisition and improved retention compared with simulation center training because there will be a more distributed training regimen with more features of deliberate practice.

Materials and Methods

Surgery residents (n = 20, post graduate years 1-5) voluntarily enrolled in an institutional review board-approved laparoscopic skills curriculum training protocol. Participation in the laparoscopic skills curriculum was a required component of the surgical residency training pro-

gram; however, the use of training data for the study was voluntary. Testing was performed at the Tulane Center for Advanced Medical Simulation, New Orleans, LA. Subjects completed a questionnaire regarding demographics, handedness, and prior experience with laparoscopic surgery; responses were recorded on Likert scales.

Subjects viewed a video demonstration of 2 fundamentals of laparoscopic surgery (FLS) tasks: peg transfer and intracorporeal suturing (FLS Program, Society of Gastrointestinal and Endoscopic Surgeons, Los Angeles, CA). With no live, interactive training, subjects performed each task once as a baseline (pretest) measure using a video-trainer consisting of the following: a Stryker Vision 2 high-definition (HD) flat-panel display with flat panel mounting arm, a 1,088 HD camera console unit, a 1,088 HD camera head with coupler, an $\times 7,000,300$ W xenon light source, a Fiberoptic light cable (Stryker, Kalamazoo, MI), and a Hopkins II laparoscope and Plexiglas box (Karl Storz Endoscopy, El Segundo, CA) all placed on a Park Trainer laparoscopic Cart (Stryker) (Fig. 1A). Performance scores were calculated and recorded for each task using time for the peg transfer and using a previously published formula that incorporates completion time, errors, and final product: $600 - (\text{time} + \text{accuracy error} * 10 + \text{incomplete knot approximation error (gap)} * 10 + \text{security error} * 10)$ ¹⁵ for the intracorporeal suturing. Subjects were stratified and randomized to home training or simulation center training based on suture scoring with peg board scores used to subdivide identical suture scores.

Group 1 (home trained, n = 10) received the Standard Minimally Invasive Training System with Joystick Simulator (3D Med, Franklin, OH), a self-contained, portable laparoscopic trainer box equipped with a joystick camera and a .3-m liquid crystal display color monitor (Fig. 1B). Additionally, subjects received a copy of the training videos, the peg transfer task, FLS suturing task, a .2-m 3-0 silk suture, a video capture device, and 10 blank media compact discs. A written log of the number of training sessions, the time for each session, and the score for each task attempt was kept by each participant. All attempts were also video recorded and digitally captured using the video-capture device. Files were transferred weekly to the compact discs and submitted for review.

Group 2 (center trained, n = 10) was given 24-hour unlimited access to the simulation center, video trainers (Fig. 1A), peg transfer task, FLS suturing task, and a .2-m 3-0 silk suture. A written log of the number of training sessions, the time for each session, and the score for each task attempt was kept by each participant. All attempts were also video recorded using the WebSP (Lioniz Software, Budapest, Hungary) interface in the simulation center.

Both groups practiced at their discretion but were encouraged to train at least 1 hour per week. The practice schedule was at the discretion of the subjects. To foster goal-directed learning, all participants were given previously established proficiency levels for the peg transfer (48

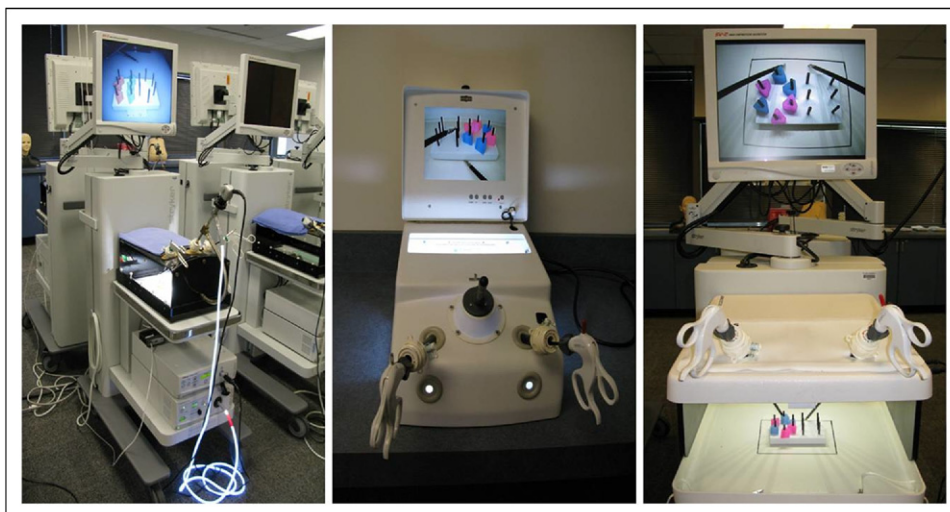


Figure 1 (A) The Stryker laparoscopic video tower on a Park Trainer Laparoscopic Cart. (B) The Minimally Invasive Surgical Trainer (Joystick Simscope). (C) FLS trainer box (FLS Program, Society of Gastrointestinal and Endoscopic Surgeons, Los Angeles, CA) with flat-panel display (Stryker).

seconds)¹⁶ and the laparoscopic suturing model (512).¹⁵ At the end of 60 days, all subjects were posttested using both tasks (peg transfer and intracorporeal suturing) in the FLS trainer box (Fig. 1C), and scores were recorded. With no further training, participants returned 60 days later and were retested on both tasks using the FLS trainer as a retention test, and scores were recorded. At the completion of training, the written training logs were collected. Video recordings were sampled and compared with the written logs to evaluate the accuracy of the written logs.

Subjects' perceptions and methods of training were evaluated by a qualitative analysis of results obtained from 2 separate focus group interviews: 1 with the home-trained group and 1 with the center-trained group. Nine subjects in each group participated in the 1-hour sessions that were conducted by one of the authors (JRK) 4 weeks after completion of the retention test. Questions regarding preconceived ideas about the training, strengths, and weaknesses of the training and individual reasons for selecting the time and pattern of training were used to guide the discussion. Both sessions were audio recorded and transcribed for analysis. A grounded theory approach was used to analyze the focus group data by initially evaluating the data within the framework of the surgical simulation literature and the motor skill learning literature but being open to the development of new themes consistent with our analysis of the focus group data. Constant comparative analysis was used to formulate themes from the focus group. Two reviewers used these themes to review all focus group data for theme frequency. Discrepancies were discussed, and the data were recoded. Example quotes supporting the main themes are included in the report of results.

Statistical analysis was performed for categorical variables using the Fischer exact test. For intragroup comparison of normally distributed data, statistical analysis was performed using 1-way repeated measures analysis of variance with

pair-wise multiple comparisons. Nonnormally distributed data were analyzed using 1-way repeated measures analysis of variance on ranks with pair-wise multiple comparison. Intergroup comparisons were done using the *t* test for normally distributed data and Mann-Whitney rank sum for nonnormally distributed data. Linear regression analysis was performed to determine relationships among total training sessions, total training time, total attempts, and posttest or retention suture scores. All analysis was performed using Sigma Stat 3.0 statistical software (SPSS, Chicago, IL). *P* < .05 was considered significant. The training group size (*n* = 10) was chosen to allow the detection of a performance score difference of 51 between the training groups with a power of .8 and an alpha level of .05. This performance difference represents 10% of the expert performance level. The performance mean and standard deviation were based on previous results on the same model.¹⁷

Results

The demographic data for the 2 groups (Table 1) showed no significant difference in age, sex, handedness, or post-

Table 1 Demographic data*

	Home trained (<i>n</i> = 10)	Center trained (<i>n</i> = 10)
Age [†]	30.9 ± 2.6	31.4 ± 3.1
Percent female	80	20
Percent left hand dominant	0	0
Postgraduate year [†]	2.8 ± 1.6	2.3 ± 1.5

**P* = not significant for all comparisons.

†Values are mean ± standard deviation.

Table 2 Training measures

	Total time (min)	Total attempts	Total sessions
Home trained	458 ± 290	86 ± 36	13 ± 8
Center trained	356 ± 133	85 ± 35	7 ± 3
<i>P</i> value	NS	NS	<.05

NS = not significant.

graduate year. All subjects completed written training logs. Six home-trained subjects kept video logs because hardware issues prevented 4 from capturing the training. All center-trained video logs were captured. A comparison of the written training logs and the sample of video-recorded logs showed that all attempts and sessions were recorded. No statistically significant differences were identified in the total training time (home trained: 458 ± 290 vs center trained: 356 ± 133 minutes) or the total number of attempts (86 ± 35 vs 85 ± 34). However, the home trained group trained for significantly more sessions (13 ± 7.8 vs 7.2 ± 2.7, $P < .05$) (Table 2). Approximate training device costs were \$35,000 for each tower video trainer (Fig. 1A) and \$2,000 for the home trainers (Fig. 1B).

Peg transfer performance scores of the home-trained group differed significantly at the 3 test intervals. On pair-wise comparison, the performance at the posttest and retention was significantly superior to pretest (Table 3). No statistically significant differences were identified between the posttest and retention test. Similarly, peg transfer performance scores for the center-trained group differed significantly at the 3 test intervals. On pair-wise comparison, the performance at posttest and retention was statistically superior to pretest; however, no statistically significant differences were identified between the posttest and retention test. Results of the intracorporeal suturing replicated that of

the peg transfer (Table 3). Performance scores of the home-trained group differed significantly at the 3 test intervals. On pair-wise comparison, the performance at the posttest and retention was superior to the pretest. No statistically significant differences were identified between the posttest and retention test. Similarly, intracorporeal suturing performance scores for the center-trained group differed significantly at the 3 test intervals. On pair-wise comparison, the performance at the posttest and retention was superior to the pretest; however, no statistically significant differences were identified between the posttest and the retention test.

An intergroup comparison of peg board performance showed no significant differences at pretest, posttest, or retention (Table 3). For intracorporeal suturing, an intergroup comparison revealed that the center group achieved better scores at the posttest, whereas the home-trained group achieved better scores at the retention test (Table 3). These differences did not reach statistical significance.

To determine if the total training time, the number of attempts, or the number of sessions affected intracorporeal suturing scores, a subset of those individuals beginning with a baseline score of 0 ($n = 8$) was evaluated. This subset was chosen for analysis to minimize the ceiling effect present in those starting at a higher baseline. No significant relationship was identified between the total training time or the number of attempts with suturing scores. However, a significant correlation (Fig. 2) was identified between the number of sessions and suturing scores ($r^2 = .54$, $P < .039$).

Qualitative analysis of the focus group interviews identified 2 main themes in both home-trained and center-trained groups: method/timing of training and challenges to training. Surprisingly, analysis did not identify the lack of direct, personal feedback as a trainee concern. Additionally, issues regarding duty hours were not raised despite training at the center being considered part of the duty hours whereas training at home was not because it was considered

Table 3 Test scores

	Peg transfer scores*			
	Pretest	Posttest	Retention test	<i>P</i> value
Home trained	135 ± 67 ^{†‡}	72 ± 19 [†]	59 ± 15 [‡]	<.05 [†] ; <.05 [‡]
Center trained	150 ± 68 ^{†‡}	60 ± 16 [†]	59 ± 16 [‡]	<.05 [†] ; <.05 [‡]
<i>P</i> value	NS	NS	NS	
	Intracorporeal suturing scores**			
	Pretest	Posttest	Retention test	<i>P</i> value
Home trained	162 ± 194 ^{†‡}	411 ± 82 [†]	429 ± 111 [‡]	<.05 [†] ; <.05 [‡]
Center trained	149 ± 196 ^{†‡}	417 ± 101 [†]	385 ± 106 [‡]	<.05 [†] ; <.05 [‡]
<i>P</i> value	NS	NS	NS	

NS = not significant.

*All scores mean ± standard deviation (scores are in seconds); lower scores are superior.

**All scores are mean ± standard deviation; higher scores are superior.

†‡Indicate the comparisons in the table that have the *p* value noted.

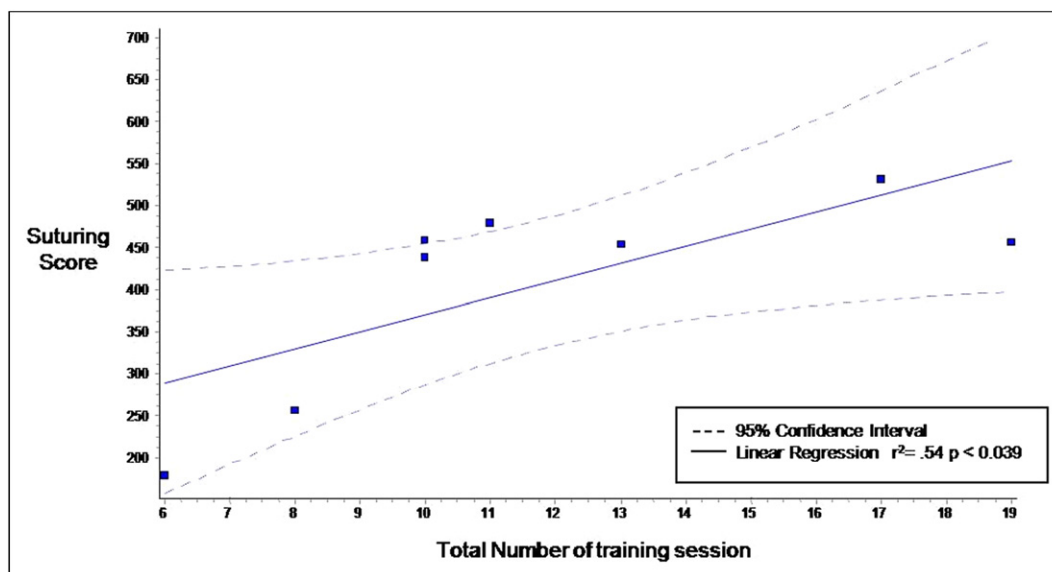


Figure 2 Linear regression analysis of intracorporeal suturing task score (higher score superior) and number of training sessions.

required self-improvement outside of the working environment. For method/timing of training, 80% of the home-trained subjects stated that they avoided training while fatigued, whereas all center-trained subjects commented that they trained during a fatigued state. The home-trained group would stop when they would “get frustrated” or “tired,” whereas the center-trained group commented the “fatigue factor made it more frustrating” and that they “got bored.” All the home-trained group divided the training time for each individual session between the peg transfer and the intracorporeal suturing tasks (random practice), whereas 90% of the center-trained group used all the training time for each individual session for a single task (blocked practice).

Challenges for the home-trained subjects focused on the equipment (eg, “oblique angle made it difficult” and the “bright white glare in the box”). However, subjects believed that training with more challenging equipment made testing in the FLS box “easier.” Challenges for the center-trained group include the need to “change schedules and reschedule” to “answering phones” while training and being “rushed most of the time.”

Comments

Simulation training using low-cost or “low-fidelity” simulators has previously been proven effective in the development of surgical skills.^{18–20} However, these studies used the simulators in a simulation center environment, which minimizes the true cost benefit of such a simulator. Additionally, simulation training at home has been shown to develop an improvement in skill.⁶ However, this prior study of home training only tested for immediate improvement and not skill retention, and the studies did not incorporate

proficiency-based curricula. Our study combines a low-cost simulator (<\$2,000) with a proficiency-based curriculum performed at trainees’ homes and tests for skill development and skill retention. This study shows that such a home-training curriculum can be used to develop laparoscopic skills. The initial skill development is equivalent to training with high-cost simulators in a simulation center and may be superior for skill retention.

The trend toward an improved performance by the home-trained group at the retention test and not at the initial posttest can be explained by the training method and timing chosen by the home group. The home group trained for the same amount of time but in a larger number of individual sessions. Our study shows a strong correlation between the retention of skill and the number of individual sessions, whereas there was no correlation between the retention of skill and the total time spent training. These more frequent but shorter training sessions allowed for training when not fatigued and with decreased interruption from standard hospital work requirements. Avoiding fatigue and interruptions possibly allows for the focused and effortful individual practice needed for deliberate practice as defined by Keith and Ericsson.²¹

There have been mixed results when investigating the effects of fatigue and stress on motor learning.^{22–25} This may be related to whether the tasks learned are learned in an implicit (unintentional and independent of working memory) or explicit (intentional and using working memory) manner.²³ Implicit motor skill development occurs without full understanding and leads to a level of automaticity. It is this level of automaticity that Ericsson⁹ has described as leading to a plateau that can hinder achieving expert performance. To improve to an expert level, continued effortful practice is required with repetitive evaluation of the actions or results of training. Constant evaluation enables the

learner to identify where improvements can be made. This type of effortful practice and deliberate practice closely mimics explicit motor learning, which has been shown to be detrimentally affected by fatigue.²³ Subjects training at home self-adjusted their training to account for such fatigue, whereas the subjects training at the center trained when scheduled despite fatigue and the center being available for training at any time. The home training may have enhanced effortful practice because subjects could devote full attention to the motor skill learning. Dividing concentration between the required motor skill learning and hospital tasks, such as answering pages and other patient-care necessities, limited the focused, effortful nature of training in the simulation center during standard hours.

The method/timing of training chosen by the subjects may also have contributed to the retention differences identified. Most of the center group practiced the 2 tasks in a blocked fashion (1 task for the full session), whereas the home group practiced the skills in a more random fashion. Blocked practice has been shown to be a better training method for immediate recall,^{12,14} but random practice, possibly through contextual interference, leads to improved skill at retention.^{10,12,14,26} Additionally, a self-regulated practice schedule has been shown to have a positive effect on motor learning retention.^{27,28} Although the development of skill is important, it is this retention of skill that should be the primary goal of all motor skill training for surgery.

One concern about any home-training curriculum that must be addressed for successful implementation includes whether trainees will train without direct supervision. The home training in this study was successful because the subjects were motivated to develop the skill set. All subjects were aware that passing the FLS certification is required to take the qualifying examination of the American Board of Surgery. However, even with other tasks not directly related to the subjects' future certification, we contend that if the skill set is deemed important by the program and this importance is conveyed through action (eg, a lack of operating room time until the skill is mastered), then a similar motivation can be created. In our regular simulation curriculum, requiring all residents that miss their scheduled training time to meet with the chair of the department to explain the absence creates this motivation. A similar methodology can be instituted using the training logs, video logs, or spot-check performance assessments in place of attendance. The requirement that the home-trained subjects video record all their sessions and turn them in weekly may have enhanced compliance in our study. However, 4 of the 10 home-trained subjects were not able to record because of hardware compatibility issues yet even including these 4 in the home-trained group, a group improvement in skill was shown. The subset of 4 who were unable to video record was too small for any meaningful analysis. All subjects did turn in weekly reports of all attempts, and of those that were able to record, 100% of the attempts and sessions in the written record were confirmed by the video files. From this, we believe

written records are a sufficient record of training provided they are routinely checked.

The primary limitation of the study is the small sample size. The expected difference of 10% between training groups at retention testing was identified; however, using residents of various levels greatly increased the standard deviation in this study compared with previous studies with more homogeneous populations. Given the standard deviation in this study, a sample size of 93 subjects would be required to identify a difference of 10% at a power of .8. The larger standard deviation seen in the assessment of more heterogeneous populations will be accounted for in a multicenter study being developed to evaluate the potential retention effect. Despite being underpowered for intergroup comparisons, the intragroup findings are important because there was a significant improvement in skill for the home-trained group at the posttest and retention when compared with pretesting. Therefore, although the study is not powered sufficiently to show that home training is definitively better than center training; it is sufficiently powered to show that home training is effective. A 2nd limitation is the lack of immediate repercussions for residents not training for at least 1 hour per week. As previously noted, voluntary training time is rarely successful.^{7,8} Although the training was a required part of the residency program, as such training has been for the past 7 years; we did not strictly adhere to the ramifications of missing a weekly practice due to of ethical concerns because this was a study protocol. Despite the lack of immediate ramifications of missing practice, the motivation to pass the FLS test provided sufficient motivation for all subjects to train.

In conclusion, home training does result in laparoscopic skill acquisition and retention and is performed in a more distributed manner, resulting in a trend toward improved skill retention when compared with standard simulation center training. Therefore, home-training curricula should be developed as a cost-effective way of skill training outside of the regular workweek. Simulation center time can then be efficiently used when training requires multiple personnel or when high-stakes assessment is required.

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