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Outcomes of Fundamentals of Laparoscopic Surgery (FLS) mastery training standards applied to an ergonomically different, lower cost platform

Sarah B. Placek[1,2] · Brenton R. Franklin[1,2] · Sarah M. Haviland[1,2] · Mercy D. Wagner[1,2] · Mary T. O'Donnell[1,2] · Chad T. Cryer[1] · Kristen D. Trinca[1] · Elliott Silverman[1,2] · E. Matthew Ritter[1,2]

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Abstract
Objective Using previously established mastery learning standards, this study compares outcomes of training on standard FLS (FLS) equipment with training on an ergonomically different (ED-FLS), but more portable, lower cost platform.
Methods Subjects completed a pre-training FLS skills test on the standard platform and were then randomized to train on the FLS training platform ($n = 20$) or the ED-FLS platform ($n = 19$). A post-training FLS skills test was administered to both groups on the standard FLS platform.
Results Group performance on the pretest was similar. Fifty percent of FLS and 32 % of ED-FLS subjects completed the entire curriculum. 100 % of subjects completing the curriculum achieved passing scores on the post-training test. There was no statistically discernible difference in scores on the final FLS exam (FLS 93.4, ED-FLS 93.3, $p = 0.98$) or training sessions required to complete the curriculum (FLS 7.4, ED-FLS 9.8, $p = 0.13$).
Conclusions These results show that when applying mastery learning theory to an ergonomically different platform, skill transfer occurs at a high level and prepares subjects to pass the standard FLS skills test.

Keywords FLS · Mastery learning · Laparoscopy · Simulation

In 2008, the American Board of Surgery adopted the Fundamentals of Laparoscopic Surgery (FLS) as a requirement for graduating general surgery residents to sit for the qualifying exam [1, 2]. This requirement has made adequate training to ensure first-time passing scores for the FLS exam exceedingly important for both general surgery trainees and program directors. Mastery learning standards were developed for each of the five FLS tasks, and studies have shown that adhering to this proficiency-based curriculum results in 100% pass rates on the FLS skills test [3–5]. Additionally, training using proficiency-based standards translates into improvement in operative skills and skill retention [5–9].

Many residency programs have incorporated FLS training and certification into their residency curriculum; however, training to proficiency using the standard FLS equipment (Fig. 1) has its drawbacks including high cost, limited portability, and the requirement for residents to use in-hospital work hours in a simulation center environment to complete training [10–12].

Several previous studies have developed, "home-made," more portable and cost-efficient laparoscopic training platforms, but these platforms have not been studied for use in proficiency-based training for the FLS skills test [13–17]. A commercially available, lower cost, more portable platform exists (Fig. 2), but like many of the "home-made" platforms, it is ergonomically different than the standard FLS platform (Fig. 3) [18]. No studies to date have evaluated the implications of training for the FLS skills test on an ergonomically different platform. It is unknown how skills gained in an ergonomically different

✉ Sarah B. Placek
sarah.b.placek2.mil@mail.mil

E. Matthew Ritter
eritter@usuhs.edu

[1] Division of General Surgery, USU/Walter Reed Department of Surgery, BLD A Room 3020, 4301 Jones Bridge Road, Bethesda, MD 20814, USA

[2] National Capital Region Simulation Consortium, Bethesda, MD, USA

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Fig. 1 Standard FLS skills testing platform

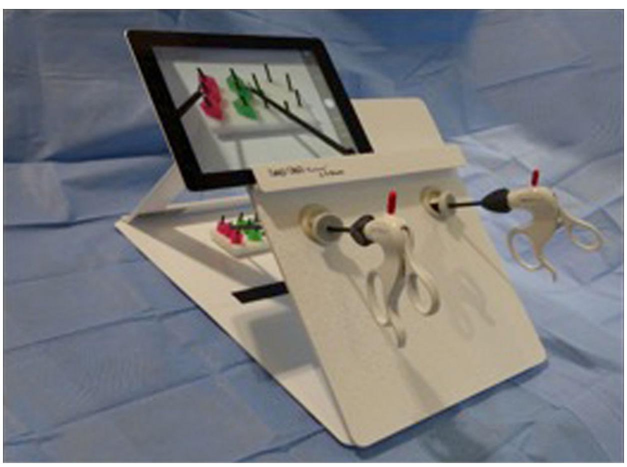


Fig. 2 Commercially available FLS platform [18]

environment would transfer to the standard FLS environment.

The objective of this study was to use previously established mastery learning standards to determine how training on an ergonomically different platform affects overall performance and score on the FLS skills test, as well as the number of training sessions and number of training trials to achieve proficiency.

Methods

Design

This was a prospective randomized trial that was granted exemption from the Uniformed Services University of the Health Sciences (USUHS) Institutional Review Board. Subjects were randomly assigned to train with either the standard FLS (FLS) or the ergonomically different FLS (ED-FLS) platform (Fig. 4). All pre-training and post-training tests were performed on the standard FLS platform and were administered by a trained FLS proctor. A representative of the FLS program using the proprietary scoring algorithm generated the test scores. Subjects were instructed to train for a goal of 60 min per session and to record each training trial. Before being allowed to train independently, each trainee was coached to ensure correct

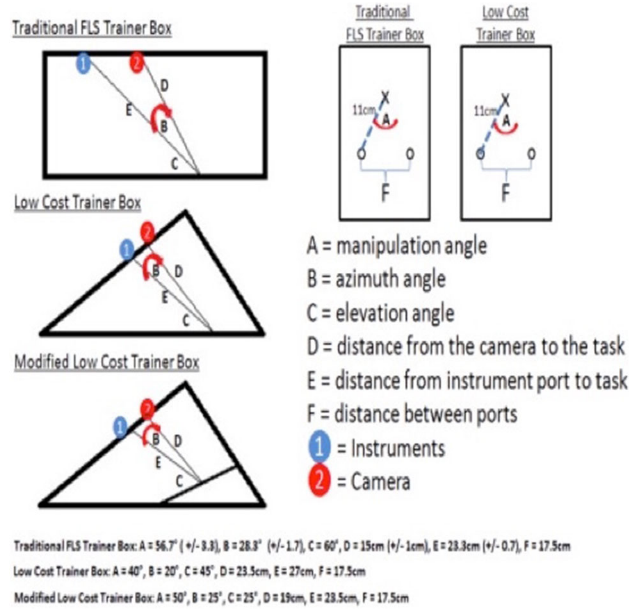


Fig. 3 Ergonomic assessment of platforms

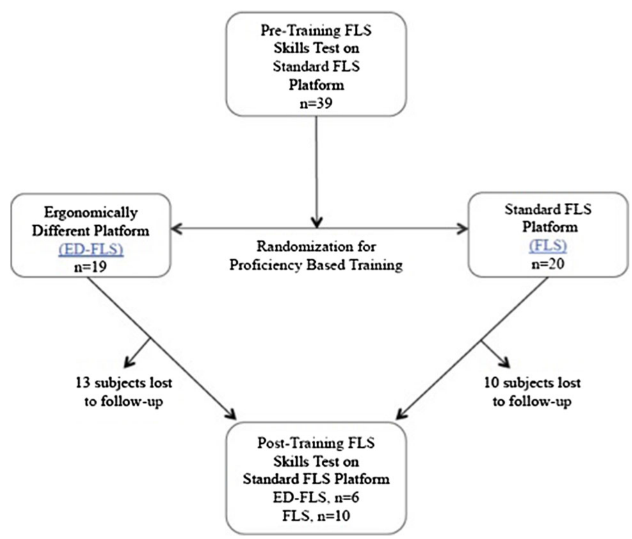


Fig. 4 Methods

technique was being used. Additional coaching was available throughout the training period as needed.

Subjects

Laparoscopic novice and medical professionals were recruited to participate. Laparoscopic novices were defined as subjects who had not completed the national FLS proficiency curriculum or been involved with more than 10 laparoscopic cases. *Inclusion criteria:* Healthcare professionals (to include but not limited to medical students, nurses, residents) >18 years of age who were novices to laparoscopy. *Exclusion criteria:* Any subject, that is <18 years of age, had no professional medical background, previously completed the FLS proficiency curriculum, or had performed >10 laparoscopic cases.

Equipment

The Lap Tab Trainer (3D Med, Franklin, OH) was used for subjects training in the ED-FLS group [18]. An ergonomic assessment of the standard FLS and ED-FLS platforms was completed (Fig. 3). Based on the analysis of the ED-FLS platform, a simple modification was made to the task display area to reduce the ergonomic differences between the FLS and ED-FLS platforms (Fig. 5) and permit reasonable performance of all five FLS tasks.

Training protocol

The mastery learning, proficiency-based training for both groups was identical and conducted using previously established performance levels for each of the five FLS tasks (Table 1) [2]. Subjects were instructed to achieve proficiency on each task before progressing to the next task (starting with task 1) or to perform a maximum of 80 repetitions when the strict proficiency definition was not met.

Fig. 5 Ergonomically different platform with modification

Statistical methods

Normally distributed, continuous variables were compared between groups using unpaired Student's t test. Non-normally distributed continuous variables were compared using the nonparametric Mann–Whitney U test. Proportions were compared using Fisher's exact test as all analyzed categorical variables had expected frequencies <5, which precludes the used of Chi-squared analysis. Relationships between continuous independent and dependent variables were explored using simple and multiple linear regressions, while relationships involving categorical dependent variables were addressed with logistic regression. Finally, the unique contribution of the training effect for the LCFLS group was analyzed using analysis of covariance (ANCOVA). The study was powered to detect a difference in posttest FLS score between groups equivalent to an effect size of 1. With alpha set at 0.05 and beta at 0.8, this resulted in an estimated 17 subjects in each group to detect this difference. As we estimated some dropout, we initially targeted an enrollment of 20 subjects in each group. All statistical analysis was performed using SPSS 22 statistical software. Data are presented in the format of mean ± standard deviation unless otherwise noted.

Results

Thirty-nine subjects were enrolled during the study period, and all completed their pre-training FLS skills test on the standard FLS platform. Nineteen subjects were randomized to the ED-FLS, and 20 subjects to the FLS training groups. There was no statistically discernible difference between the groups on the FLS pretest (FLS, 19.5 ± (11.4), ED-FLS, 18.2 ± (17.9) (Fig. 6). Sixteen out of thirty-nine subjects (41%) completed the proficiency-based training and performed the post-training FLS skills test (FLS, $n = 10$ (50%); ED-FLS, $n = 6$ (32%), $p = 0.34$) and were included in final analysis (Fig. 4).

Demographics were similar between both groups for all subjects that enrolled (Table 2), and all subjects that completed the curriculum (Table 3), with respect to age, gender, handedness, previous laparoscopic experience, and previous FLS experience. One subject in the FLS group achieved the minimum FLS passing score on the pre-training skills test. Hundred percent of subjects completing the curriculum in both groups achieved a passing score on the post-training skills test (Fig. 7). Of the subjects completing the curriculum, the ED-FLS group had significantly lower pre-training scores, despite both groups performing

Table 1 Summary of proficiency standards

Task	Seconds	Errors allowed	Repetitions[a]
Peg transfer	48	No drops outside field of view	2 Consecutive + 10 non-consecutive
Pattern cut	98	All cuts within 5 mm lines	2 Consecutive
Endo-loop	53	Up to 1 mm accuracy error allowed	2 Consecutive
Extracorporeal knot tying	136	Up to 1 mm accuracy error allowed	2 Consecutive
Intracorporeal knot tying	112	Up to 1 mm accuracy error allowed	2 Consecutive + 10 non-consecutive

[a] Maximum of 80 repetitions for each task

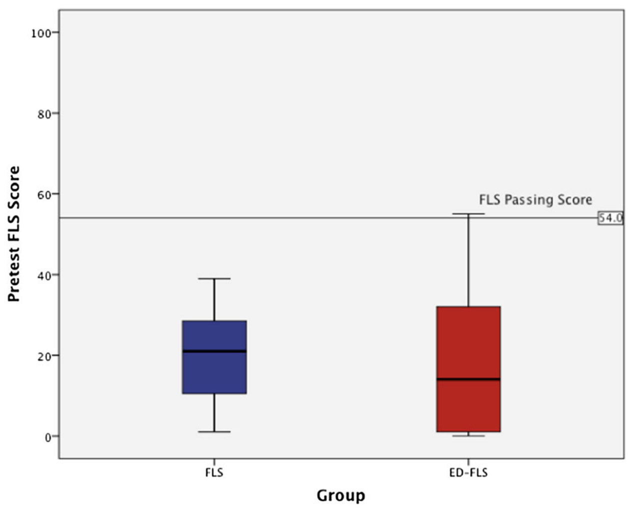


Fig. 6 Pretest score comparisons on all randomized subjects

their pretest on the standard FLS platform (FLS 25.9, ED-FLS 12.8; $p = 0.02$) (Fig. 7A). Despite this lower mean pretest score in the ED-FLS group, there was no statistically discernible difference in scores on the final post-training FLS exam (FLS 93.4, ED-FLS 93.3; $p = 0.98$) (Fig. 7B). The unique contribution of the training effect for the ED-FLS group was analyzed using analysis of covariance. The model satisfied the parallel slopes assumption. After controlling for performance on the pretest, subjects in the ED-FLS group scored 3.6 points higher than the estimated marginal mean on the posttest than subjects in the FLS group ($F_{(2,15)} = 3.36$, $p = 0.07$), but this difference was not statistically significant. The ED-FLS training effect accounted for 14% of the variance in posttest FLS scores ($R^2 = 0.14$), while performance on the pretest accounted for 34% of the variance ($R^2 = 0.34$).

Table 2 Demographics of all subjects enrolled in study

Variable	Standard FLS group ($n = 20$)	Ergonomically different FLS group ($n = 19$)	p value
Mean age in years (STD)	24.1 (2.6)	26.3 (5.3)	0.12
Male	13	14	0.73
Right-hand dominant	16	15	1.0
Previous laparoscopic experience	2	2	1.0
Previous FLS experience	1	3	0.34

Table 3 Demographics of all subjects that completed the curriculum

Variable	Standard FLS group ($n = 10$)	Low-cost FLS group ($n = 6$)	p value
Mean age in years (STD)	23.2 (1.5)	23.7 (1.2)	0.53
Male	8	3	0.30
Right-hand dominant	8	6	0.5
Previous laparoscopic experience	1	1	1.0
Previous FLS experience	1	1	1.0

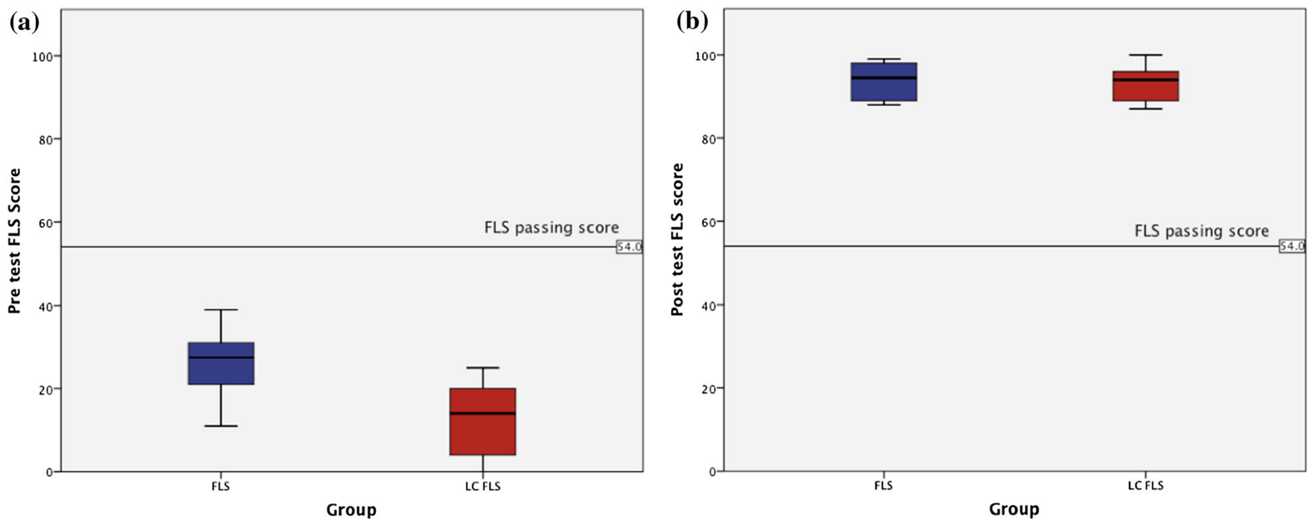
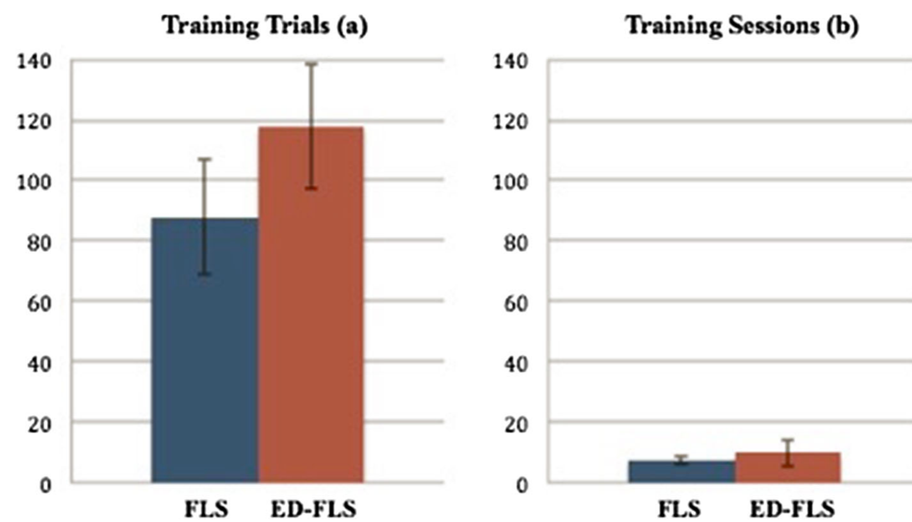


Fig. 7 **A** Pre-training (*left*); **B** post-training (*right*) outcomes of subjects who completed the mastery learning curriculum

Fig. 8 Training events required to achieve proficiency



The mean total number of training sessions required to complete the curriculum was not statistically discernible between the two groups (FLS 7.4, ED-FLS 9.8, $p = 0.13$). However, the mean number of training trials totaled across all tasks was higher for the ED-FLS group (FLS 87.9, ED-FLS 117.7, $p = 0.01$) (Fig. 8). When evaluating the training trials for each individual task, the number of peg transfer trials in the ED-FLS group was significantly higher (FLS 43.2, ED-FLS 70.17, $p < 0.001$). There were no other statistically discernible differences in training trials between groups on the four remaining tasks.

A total of seven subjects had mastery learning protocol violations that occurred during the study (3 in ED-FLS (43%); 4 in FLS (57%). All violations occurred with the number of non-consecutive proficient repetitions during peg transfer or intracorporeal knot tying. In all cases, subjects performed two consecutive repetitions to proficiency and then failed to perform at least 10 non-consecutive repetitions to proficiency. Binary logistic regression analysis demonstrated that the incidence of protocol violation between the groups was not statistically discernible (OR $= 1.15$, $p = 0.9$) and therefore likely did not contribute significantly to our results.

For the 23 subjects who did not complete the curriculum, the proficiency-based, mastery learning standard was achieved for more tasks in the FLS group than the ED-FLS group (FLS, $n = 10$, mean completed tasks $= 2.67 \pm (1.65)$; ED-FLS, $n = 13$, mean completed tasks $= 1.30 \pm (0.48)$, $p = 0.03$).

Discussion

Our results indicate that when using proficiency-based, mastery learning standards to train for the FLS skills test, the previously demonstrated 100% pass rate [4] is still maintained despite the ergonomic differences of the training platform. Additionally, post-training scores for both groups were not meaningfully different, despite the ED-FLS group having a statistically lower pretest score. The 100% pass rate and similar post-training scores of the ED-FLS group were achieved without significantly more training sessions, but did require more total training trials. The fact that this difference in pretest scores disappeared completely on post-training scores highlights the power of mastery learning in getting learners, who start at all different levels of performance, to a desired and more uniform level of achievement after completion of the curriculum.

When evaluating the individual tasks, peg transfer was the only task found to contribute to the significantly lower pretest score (performed on the standard platform) and the significantly higher number of training trials in the ED-FLS group. The remaining four pre-training task scores and total number of training trials required to achieve proficiency for the other four tasks were not discernably different.

One may argue that the ergonomic differences make the peg transfer tasks more difficult, thus requiring more trials to achieve proficiency; however, we believe the statistically discernible difference between the groups on the pre-training exam (performed on the identical standard platform) indicates that the increased number of total training trials to achieve proficiency is likely due to inherent differences (weaker starting point) of the subjects themselves. From our data, it is difficult to definitively conclude whether the increased number of trials required to achieve proficiency for peg transfer is due to ergonomic difficulties of the platform itself or simply due the fact the subjects were weaker on peg transfer to begin with. This is one limitation of our study. We perhaps would have been able to draw a more definitive conclusion in regards to this with a larger sample size or with randomization based on pre-training scores, eliminating this difference between the two groups.

Another limitation of our study is our 59% dropout rate, which was higher than anticipated. Part of the dropout rate is likely attributable to logistical considerations of our subjects. All subjects were medical students, many of whom advanced to their clerkship rotations during the study period. Given the clerkships offered at the Uniformed Services University School of the Health Sciences are spread across the country from Washington, D.C., to Honolulu, HI, subjects who did not finish the curriculum prior to advancing to their clerkship rotations were often lost to follow-up. Another factor likely contributing to subject dropout is the fact that similar to training for athletic or musical endeavors, proficiency-based, repetitive, deliberate practice to achieve a surgical skill at a high performance level is not always easy or fun. Students without a strong interest in surgery or without high motivation were often difficult to entice back into the lab if they had not progressed quickly past the first task in their first few sessions.

The major risk with a small sample error is a type II error. Given the mean difference in posttest scores between each groups (mean 0.1, standard deviation 4.6), in order to power the study at 80% with an alpha of 0.5, we would have needed over 33,000 subjects in each group, which is impractical. Additionally, even with a small sample completing the curriculum, the difference between the pretest and posttest scores for each group is already highly statistically discernible and results in an effect size of 7. The higher dropout rate and lower mean task completion rate of the ED-FLS group likely indicates that at least for this cohort of subjects, the ergonomically different platform was possibly more frustrating for subjects, at least for the early tasks (peg transfer and pattern cut).

Despite these limitations, our data show that subjects who trained to proficiency on an ergonomically different platform showed no difference in pass rate, passing score, or number of training sessions required to achieve proficiency.

Conclusions

We believe these results demonstrate that when you apply mastery learning theory to any ergonomically different platform, whether it is the commercially available one that we used, or a "home-made" platform, skill transfer should occur at a high level and prepare students to pass the FLS skills test. There is no need for repeated standard setting on each platform, as long as the platforms share basic similarities. The ergonomically different, more portable, lower cost platform in this study can be used to help learners prepare for the FLS skills exam and could potentially facilitate training for the FLS skills test outside the current, in-hospital simulation environment.

Compliance with ethical standards

Disclosures The authors Sarah B. Placek, Brenton R. Franklin, Sarah M. Haviland, Mercy D. Wagner, Mary T. O'Donnell, Chad T. Cryer, Kristen D. Trinca, Elliott Silverman, and E. Matthew Ritter have no conflicts of interest or financial ties to disclose.

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