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Research Paper

Development of laparoscopic skills in skills-naïve trainees using self-directed learning with take-home laparoscopic trainer boxes

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ABSTRACT

Background: To determine if take home laparoscopic trainer boxes with only self-directed learning can develop laparoscopic skills in surgically naive learners.
Methods: 74 starting PGY1 OB/Gyn residents and OB/Gyn clerkship medical students volunteered for the study. Learners performed a laparoscopic peg transfer task with only task instructions and no additional training. Initial tasks were recorded and scored. The participants took home a laparoscopic trainer box for 3 weeks to practice without guidance and returned to perform the same task for a second/final score. Initial and final scores were compared for improvement. This improvement was compared to practice and variables such as demographics, surgical interest, comfort with laparoscopy, and past experiences.
Results: Mean peg transfer task scores improved from 287 (SD = 136) seconds to 193 (SD = 79) seconds ($p < 0.001$). Score improvement showed a positive correlation with number of home practice sessions with a linear regression R^2 of 0.134 ($p = 0.001$). More practice resulted in larger increases in comfort levels, and higher comfort levels correlated with better final task scores with a linear regression R^2 of 0.152 ($p < 0.001$). Interest in a surgical specialty had no impact on final scores or improvement. Playing a musical instrument and having two or more dexterity-based hobbies was associated with a better baseline score ($p = 0.032$ and $p = 0.033$ respectively), but no difference in the final scores or score improvement. No other past experiences impacted scores.
Conclusions: Our study demonstrates that the use of home laparoscopic box trainers can develop laparoscopic skills in surgical novices even without formal guidance or curriculum.

Key message

Out study demonstrates that use of home laparoscopic box trainers can develop laparoscopic skills in surgical novices even without formal guidance or curriculum, which is significant as it could help overcome time and cost barriers with traditional training labs, and be used by training programs to implement skills training in a more simple and accessible fashion.

Introduction

Laparoscopic surgery and other minimally invasive techniques have become standard of care in gynecology and many other surgical specialties. Skills training in laparoscopic surgery is an essential part of surgical residencies and is increasingly sought after by students in medical undergraduate education. In the interest of patient safety however, hands on experience in laparoscopic surgery is often limited for postgraduate year 1 (PGY1) resident physicians, and to a greater extent, medical students. Simulation based training has become the standard in initial laparoscopic skill acquisition to ensure that trainees can learn basic techniques in a safe environment. Multiple studies have demonstrated that simulation improves surgical performance and assessment systems such as MISTELS are validated to determine competent surgical performance [1–3]. This has been extensively studied in residents, but more recent data suggests that simulation training can develop laparoscopic skills in medical students as well [4–8]. Studies have shown that medical students are interested in laparoscopic training and surgeons agree that education in laparoscopy is important for medical students [9]. Involving medical students in laparoscopic training sessions may also improve students' interest in surgical fields

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[7].

Despite the recognition of the importance of laparoscopic simulation training, barriers still exist in implementing training programs [5]. Resident physicians experience financial constraints (training equipment is expensive) and time constraints (especially when trainers are only available in a simulation center), which limits the ability for them to participate in simulation [10,11]. For medical students, the lack of formalized integration of laparoscopic skills training into their education limits exposure to a few elective experiences. Financial barriers are also more pronounced, as the high costs of laparoscopic trainers are less justifiable given laparoscopic training is not considered as essential for students as it is for surgical residents [5]. There is a need to find more accessible ways to provide laparoscopic training to medical students and resident physicians early in training.

Using laparoscopic trainer boxes at home offers a potential solution to some of the barriers to training, namely limited time and finances, due to the availability of cheaper, portable alternatives. A few small studies with residents in various surgical fields have demonstrated that with instruction sessions and home trainer boxes, residents can develop skills just as well as when practicing on more high tech simulation equipment in simulation centers, and there is some evidence that they may practice more frequently [11–13]. Additionally, a few studies have demonstrated that low cost "do-it-yourself" assembled trainer boxes are just as effective at developing skills as more expensive commercial trainers when used in simulation labs, creating potential for a less expensive option for home trainer boxes [5,14]. Despite early evidence of their potential utility in residents, there is little to no evidence of its utility in medical students. Our literature search revealed only one small pilot study that examined a mirror based instead of video based home trainer [15]. Similarly, there are very limited studies that examine whether these trainer boxes can still develop skills when the learning is *self-directed* instead of formal training session and curriculum based, a strategy that has potential to save time and resources thus limiting barriers to training.

Our study aims to evaluate the utility of home laparoscopic trainer boxes with self-directed learning in both medical students and surgically naive PGY1 OB/Gyn resident physicians. Our primary goals are to determine whether training with these boxes in the absence of a curriculum or formal expert guidance can still produce improvements in laparoscopic skills, and to evaluate how practice patterns impact skill improvement. We hypothesize that with enough practice, trainees can still improve their basic laparoscopic skills even without formal guidance. We are additionally interested in secondary outcomes of evaluating interest in the trainers, impact of the trainers on interest in surgery, and whether certain variables such as interest in a surgical specialty or past hobbies impact practice patterns or skill improvement.

Materials and methods

Study participants

Participants in the study were recruited voluntarily between October of 2019 and October of 2021. All medical students beginning their 3rd year OB/Gyn clerkship or 4th year OB/Gyn elective (if they did not participate in their 3rd year already), and PGY1 OB/Gyn resident physicians within the first 3 months of their residency training were invited to participate via a standard email invitation. PGY1 OB/Gyn residents were included in the study as we wanted to evaluate the effect of the trainers on surgically naïve trainees. PGY1 Ob/Gyn residents at our institution do not receive laparoscopic surgery exposure until late into their first year, so a similar baseline skill level as the medical students was expected. Upon agreeing to participate in the study, participants were asked to fill out a pre-test survey that collected basic demographic information, year of medical school or residency, handedness, experience with laparoscopy, comfort with laparoscopic tasks, current specialty or subspecialty interest, and experience with video games, musical instruments, sports, or other hobbies requiring fine hand motor skills. The study was approved by the Northwell Health Institutional Review Board (IRB 19-0230).

Initial live session

After completing the pre-test, participants were scheduled for a live laparoscopic training session with a proctor. At the session, participants were given a Lap Tab Trainer (3-Dmed, Franklin, OH) (Image 1), one laparoscopic Maryland grasper, one laparoscopic blunt grasper, and a "post and sleeve" laparoscopic task insert (3-Dmed, Franklin, OH) (Image 2). Trainers, instruments, and laparoscopic task were all purchased directly from 3-Dmed by the department of OB/Gyn at our institution using department funds. Participants were then given verbal and written instructions by the proctor on how to perform a peg transfer using the given instruments and task insert that was based off the peg transfer task in the McGill Inanimate System for Training and Evaluation and Training of Laparoscopic Skills (MISTELS) [16]. Fig. 1 lists the explicit instructions given in full. Participants were only given verbal and written instructions; no visual demonstration was provided.

After instructions were completed, participants were given 10 min to practice the task and familiarize themselves with the trainer. No guidance on how to perform the task nor feedback from the proctor was given at this time, though any clarification questions about task instructions were answered. At the end of the 10 min, participants then completed the task while recording themselves on the phone that was being used as the camera for the trainer. Videos were deidentified and then watched and scored by another investigator. This investigator was not a proctor, only saw the participants' study IDs, and was blinded to the participants' demographics and survey answers. Videos were scored by counting the total time to complete the task and adding the penalty for pegs dropped outside the field of view, similar to scoring for the peg transfer task in the MISTELS assessment [2]. This peg drop penalty was a proportion of the participant's task completion time, calculated as 1/6th of the total time if the peg was dropped when transferring from left to right, or 1/12th of the total time if the peg was dropped when transferring from right to left. The smaller penalty for a drop during right to left transfer was to account for the fact that the left to right transfer for that peg had already been completed successfully at that point. In equation form, the score is the following

$$T + \left(T \times \frac{L}{6}\right) + \left(T \times \frac{R}{12}\right)$$

where T is time to complete the task, L is the number of drops out of view

Image 1. Lap Tab Trainer (3-Dmed, Franklin, OH)

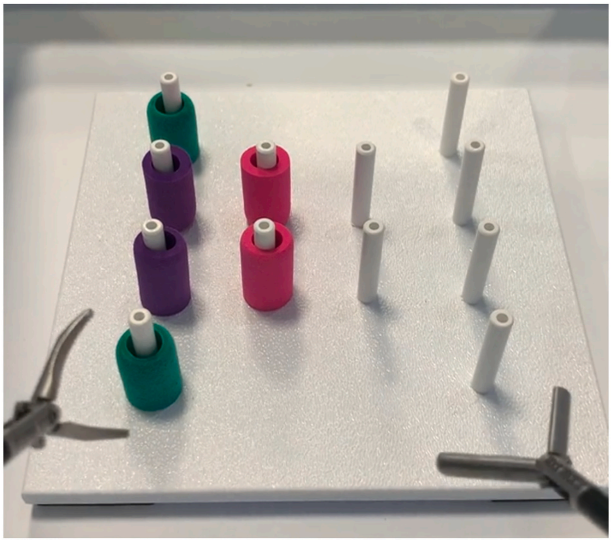

Image 2. "Post and sleeve" laparoscopic task insert (3-Dmed, Franklin, OH) in use within Lap Tab Trainer

transferring from left to right, and *R* is the number of drops out of view transferring from right to left. Participants were never informed of their scores on the task.

Practice at home

Upon completion of the live session, participants were given the equipment to take home for 3 weeks. They were instructed to practice as much or as little as they desired, and to record every practice session on a provided log sheet. The logs included the start and end times of each practice session, what task they practiced (participants were informed that if they wished to use other materials they had such as sutures to practice laparoscopic skills instead of the peg board they were welcome to), and whether they practiced alone or with an instructor (instructor being defined as any attending or resident PGY2 and above). They were informed that at the end of the 3 weeks they will return for a second live session where they will record themselves performing the task again and that this would be compared to their initial session to assess for improvement. The log sheet was collected at the second session and sent to the video grading investigators, who entered the information on the log sheets, including the total amount of time practiced in minutes and total number of practice sessions.

Final live session

At the second live proctored session, the task instructions were again briefly reviewed, and the participants were asked to perform the task and record it. No additional time was given to practice at the second session prior to recording the task. These videos were again deidentified and evaluated by a blinded investigator using the same scoring criteria as the initial video. Participants were not told their final score. At the end of their live session, participants returned the trainer and equipment, and filled out a post-test survey which asked them if they felt their skills improved during the 3 weeks they had the trainer, their comfort level performing laparoscopic tasks, whether they would like to keep the trainer for longer if given the option, whether they would practice laparoscopic skills regularly if provided with a trainer at home, and their current specialty or sub-specialty interest.

Data analysis

Data was then used to assess for overall score improvement, as well as trends in task scores and improvement as they compared to practice, past experiences, interest, and perceived comfort. Specifically, improvement in task scores between the initial and final sessions was compared to total practice time and number of practice sessions, reported comfort levels with laparoscopic tasks was compared to respective initial and final score values, and change in comfort levels was compared to the total practice time and number of practice sessions. Each of these comparisons was statistically analyzed using a linear regression, where a relationship between the two variables was considered statistically significant if the coefficient of the trend-line had a p value of <0.05. Sex, specialty interest, past laparoscopic experience,

1) Start with all pegs on the left side of the board,
2) Insert one grasper each into the two ports on the front of the trainer and hold one grasper in each hand. It does not matter which type of grasper is in which hand, this is up to your preference, and you may switch at any time during the task if you desire.
3) Start by lifting one of the pegs off the post with your left hand, then once it is off the post, transfer it to your right hand in midair and then use your right hand to place it down onto one of the posts on the right side.
4) Continue this process with each peg until all 6 pegs are on the right side of the board. The order in which you transfer the pegs, and which post they get placed on is up to you, as long as all pegs end up on the right side.
5) Once all pegs are on the right, repeat the process in reverse, using your right hand to lift a peg off its post, transfer it to your left hand in midair, then place it down on the left side.
6) Repeat this for each peg until all pegs are back on the left side.
7) If a peg is dropped and it is still in the field of view of the camera, it must be picked up with the hand that dropped it and the task continued. The drop cannot be used as the point of transfer between two hands. No penalty will be assessed for this drop as having to retrieve the peg will inherently add to the time needed to complete the task.
8) If a peg is dropped outside the field of the camera's view, it cannot be retrieved, and you are to continue the task with the remaining pegs. A time penalty will be incurred from this type of drop.
9) Time for the task starts when the first peg is touched with a grasper and ends when the last peg is returned to the left side of the board.

Fig. 1. Verbal instructions provided to participants on how to complete peg transfer task.

handedness, tasks practiced, instructor use, and experience with video games, musical instruments, sports, and other hobbies involving fine hand motor skills were each compared individually to initial scores, final scores, and improvement in scores using a student *t*-test. Relationships between the two compared variables were considered significant if the student *t*-test revealed a p value of <0.05. Changes in interest in using the trainer and any changes in specialty interest over the course of the study were evaluated qualitatively.

Results

Score improvements and practice

74 total individuals participated in the study, 39 were medical students and 35 were PGY1 OB/Gyn residents (Table 1). The mean initial task score was 287 (SD = 136) seconds and mean final task score was 193 (SD = 79) seconds, giving a statistically significant mean improvement of 94 (SD = 143) seconds ($p < 0.001$). Eight of the participants did not practice at home at all during the 3-week period. Their mean initial task score was 227 (SD = 51) seconds and final task score was 252 (SD = 110) seconds, a worsening of their score by 25 (SD = 85) seconds that was not statistically significant ($p = 0.44$). Evaluating the remaining 66 participants who practiced at least once, the mean initial score was 295 (SD = 141) seconds and mean final score was 185 (SD = 72) seconds, an improvement of 110 (SD = 143) seconds ($p < 0.001$). Participants who practiced only one time ($n = 13$) also had a statistically significant improvement in score of 79 (SD = 104) seconds ($p = 0.02$) (Table 2). When the medical students were evaluated alone, the mean initial task score was 278 (SD = 115) seconds and mean final task score was 183 (SD = 78) seconds, giving a statistically significant mean improvement of 95 (SD = 122) seconds ($p < 0.001$). The mean total practice time over 3 weeks was 69 (SD = 65) minutes for the entire study group. There was a significant difference in practice time between PGY1 residents (47, SD = 47, minutes) and students (90, SD = 73, minutes) ($p = 0.004$) (Table 3). Mean total practice sessions over 3 weeks was 4.0 (SD = 3.8) for the whole group. There was also a significant difference in number practice sessions between PGY1 residents (2.5, SD = 2.1) and students (5.2, SD = 4.5) ($p = 0.002$). There was no statistically significant difference between the mean initial scores and mean final scores of students, 278 (SD = 115) and 183 (SD = 78) seconds, vs PGY1 residents, 297 (SD = 158) and 203 s (SD = 80) ($p = 0.56$ and $p = 0.26$ respectively).

Total practice time in minutes did not show a significant association with score improvement as a percentage ($p = 0.20$) but a higher number of practice sessions did show an association with a larger percentage score improvement ($p = 0.001$) (Fig. 2). Subjective comfort level with laparoscopic tasks was not associated with a better score during the initial session ($p = 0.054$), but a higher subjective comfort level with laparoscopic tasks at the final session was associated with a better final score ($p < 0.001$) (Fig. 3). Improvement in subjective comfort level with laparoscopic tasks between the initial and final sessions was associated with both total time practiced and number of practice sessions (p < 0.001 and $p = 0.014$ respectively) (Fig. 4).

Impact on interest in laparoscopic training and surgical specialties

Prior to the initial session, 51 participants (68.9 %) reported they would practice laparoscopic skills regularly if provided with a trainer to take home, while 2 (2.7 %) reported they would not, and 21 (28.4 %) were unsure. For PGY1 residents, these numbers were 25 (71.4 %), 1 (2.9 %), and 9 (25.7 %) respectively and for students they were 26 (66.7 %), 1 (2.6 %), and 12 (30.8 %) respectively. After the final session, 57 participants (77.0 %) reported they would practice laparoscopic skills regularly if provided with a trainer to take home, while 4 (5.4 %) reported they would not, and 13 (17.6 %) were unsure. For PGY1 residents, these numbers were 31 (88.5 %), 1 (2.9 %), and 3 (8.6 %) respectively, and for students they were 26 (66.7 %), 3 (7.7 %), and 10 (25.6 %) respectively. 77.0 % of all participants reported they would like to keep the trainer for longer at the end of the study, with 94.3 % of PGY1 residents and 64.1 % of student participants reporting this. Among medical students, 19 participants were interested in a surgical specialty including OB/Gyn at the beginning of the study, 13 were unsure of their specialty choice, and 7 were interested in a medicine specialty. The net number of students interested in surgery did not change at the end of the study and remained at 19, with one student previously interested in surgery reporting they were unsure at the end of the study, and one of the previously unsure students deciding they were interested in surgery at the end of the study.

For the entire study group, the specialty or sub-specialty interest of the participant had no statistically significant impact on initial score, final score, score improvement, practice time, or number of practice sessions (Table 4). When evaluating the student population alone, students who had either no interest in a surgical specialty or were unsure about specialty interest had 2.8 more practice sessions on average than students who were interested in a surgical specialty ($p = 0.0496$). There was no difference in scores, or total time practiced. When evaluating PGY1 residents alone, residents who had an interest in a surgically focused fellowship track (defined as gynecologic oncology, female pelvic medicine and reconstructive surgery, or minimally invasive gynecologic surgery) had an average initial score that was 94 s faster than PGY1 residents not interested in a surgically focused fellowship (p = 0.04). This advantage did not persist in final scores, nor did fellowship interest have an impact on improvement percentage, total time practiced, or number of practice sessions.

Impact of demographics and past experiences on task scores

Linear regressions of age compared to initial score, final score, and improvement in scores showed no statistically significant trend ($p = 0.38$, 0.73, and 0.79 respectively). Impact of sex, handedness, laparoscopy experience, tasks practiced, use of instructor, video game experience, musical instrument experience, competitive sport experience, other fine hand motor skill hobby experience, and a composite of number of past motor skill hobbies on scores and score improvements are listed in Table 5. Statistically significant findings included a 64 s faster initial score among participants who played musical instruments currently or in the past ($p = 0.032$) as well as a 101 s faster initial score among participants who had two or more fine motor skill hobbies (video games, instruments, sports, or other) compared to those who had 0 or 1 of these hobbies ($p = 0.033$). However, the differences in both groups

Table 1
Participant demographics and background experience ($n = 74$).

Sex	Male	22
	Female	52
Year	MS3	38
	MS4	1
	PGY1	35
Dominant hand	Right	65
	Left	5
	Ambidextrous	4
Residency or fellowship interest	Medical/general	29
	Surgical	32
	Unsure	13
Prior laparoscopic instrument or camera use	Yes	46
	No	28
Video game use?	Yes	28
	No	46
Plays musical instrument?	Yes	35
	No	39
Plays competitive sport?	Yes	42
	No	32
Other fine hand motor skill hobby?	Yes	43
	No	31

Table 2
Scores and score improvement by number of times practiced.

Number of times practiced	Initial score (seconds)	Final score (seconds)	Mean improvement (seconds)	Mean improvement Percentage[a]	Improvement significance
All ($n = 74$)	287 (SD = 136)	193 (SD = 79)	94 (SD = 143)	24.0 % (SD = 36.0)	$p < 0.001$***
0 ($n = 8$)	227 (SD = 51)	252 (SD = 110)	−25 (SD = 85)	−9.1 % (SD = 36.5)	$p = 0.43$
1+ ($n = 66$)	295 (SD = 141)	185 (SD = 72)	110 (SD = 143)	28.0 % (SD = 34.0)	$p < 0.001$***
1 ($n = 13$)	267 (SD = 112)	188 (SD = 66)	79 (SD = 104)	21.9 % (SD = 34.4)	$p = 0.02$*
2–3 ($n = 18$)	301 (SD = 201)	192 (SD = 68)	109 (SD = 194)	22.9 % (SD = 36.0)	$p = 0.03$*
4–5 ($n = 18$)	286 (SD = 111)	196 (SD = 97)	90 (SD = 116)	26.2 % (SD = 35.9)	$p = 0.004$**
6–9 ($n = 10$)	280 (SD = 111)	174 (SD = 51)	106 (SD = 104)	30.2 % (SD = 30.7)	$p = 0.01$**
10+ ($n = 7$)	372 (SD = 121)	154 (SD = 47)	218 (SD = 144)	54.2 % (SD = 21.8)	$p = 0.007$**

[a] Mean improvement percentage is calculated as the mean of each participant's individual improvement percentage, not as the improvement percentage of the mean scores.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 3
Scores and practice logs of PGY1 residents vs students.

	PGY1 residents ($n = 35$)	Students ($n = 39$)	Significance
Initial score	297 (SD = 158) seconds	278 (SD = 115) seconds	$p = 0.55$
Final score	203 (SD = 80) seconds	183 (SD = 78) seconds	$p = 0.26$
Mean improvement %[a]	21.1 % (SD = 39.5 %)	26.7 % (SD = 32.8 %)	$p = 0.51$
Time practiced	47 (SD = 47) minutes	90 (SD = 73) minutes	$p = 0.003$**
Number of practice sessions	2.5 (SD = 2.1)	5.2 (SD = 4.5)	$p = 0.002$**

[a] Mean improvement percentage is calculated as the mean of each participant's individual improvement percentage, not as the improvement percentage of the mean scores.
** $p < 0.01$.

went away for final scores and score improvement as there were no statistical differences in these values among participants regardless of past hobbies. A linear regression of number of past hobbies (0–4) vs initial score also showed a statistically significant trend towards better (lower) scores as number of hobbies increased with a coefficient of −59.4 ($p < 0.001$) and R^2 of 0.18, but a regression of number of past hobbies vs final score and score improvement showed no significant trend. There were similarly no statistically significant differences in initial scores, final scores, or score improvements between participants of different sex, handedness, past laparoscopy experience, video game experience, competitive sport experience, or other fine motor skill hobby experience.

Discussion

Home trainer boxes

Our data demonstrates that surgical skills naïve trainees can improve their laparoscopic skills using home trainers with minimal guidance and a short amount of practice. This is supported by the significant overall improvement in task scores at the post-test of the entire cohort as well as the improvement in scores for students alone. The positive effect on skills of practice with the home trainers is similarly supported by the fact that the eight participants that did not practice at home did not improve their scores between the two sessions and had a non-significant trend towards worsening, possibly due to there being no 10-min practice period before the recording at the second session, unlike the first. There was no difference in initial or final scores between the students and residents, supporting our hypothesis that they would have a similar skill level as the students due to not having any laparoscopic exposure yet and thus be comparable for training purposes. Students did, however, practice more on average both in terms of time and number of sessions compared to PGY1 residents, which is likely due to the time constraints in residency. Regarding the effect of amount of practice on scores, there was no significant association between number of minutes practiced and improvement in scores, but there was a significant correlation between increasing number of practice sessions and improved task scores.

Previous research in the use of take-home laparoscopic trainer boxes have demonstrated their utility in developing laparoscopic skills in resident physicians for practice after initial training sessions. A study by Thinggaard et al. in 2019 evaluated the utility of home trainers by giving a supervised course and curriculum and randomizing half of a cohort of 36 PGY1 OB/Gyn, general surgery, and urology residents to taking home a box trainer for practice and the other half to only having access to the simulation lab. They found that both groups improved without any differences in performance or scores, but that the take home box group did practice more frequently though not more in overall time [11]. Wilson et al. in 2019 provided home trainer boxes and a structured training curriculum with video instructions to 36 OB/Gyn residents and found that all participants showed significant improvement, though they were unable to assess practice time vs improvement statistically [12]. Wilson's study also randomized half of its participants to having a remote supervisor to evaluate practice videos and provide feedback and they found no differences in performance between the two groups. A 2012 study by Korndorffer et al. evaluated 20 surgical residents by providing a training session and then allocating half of the participants to practice with a home box trainer for 60 days and the other half to access to the simulation center only. They found that both groups improved their skills with no differences, and that the number of training sessions but not total time correlated with better laparoscopic suturing scores [13]. Our study reaffirms these findings of improvement with home trainers with a larger sample size of 74, and we add to the literature by demonstrating that these improvements can be seen in medical students as well, a less-studied group. One study by Robinson & Kushner in 2006 did involve medical students, providing a mirror-based box trainer to half of a group of 26 medical students and comparing them to a control group of laparoscopic based tower training. They

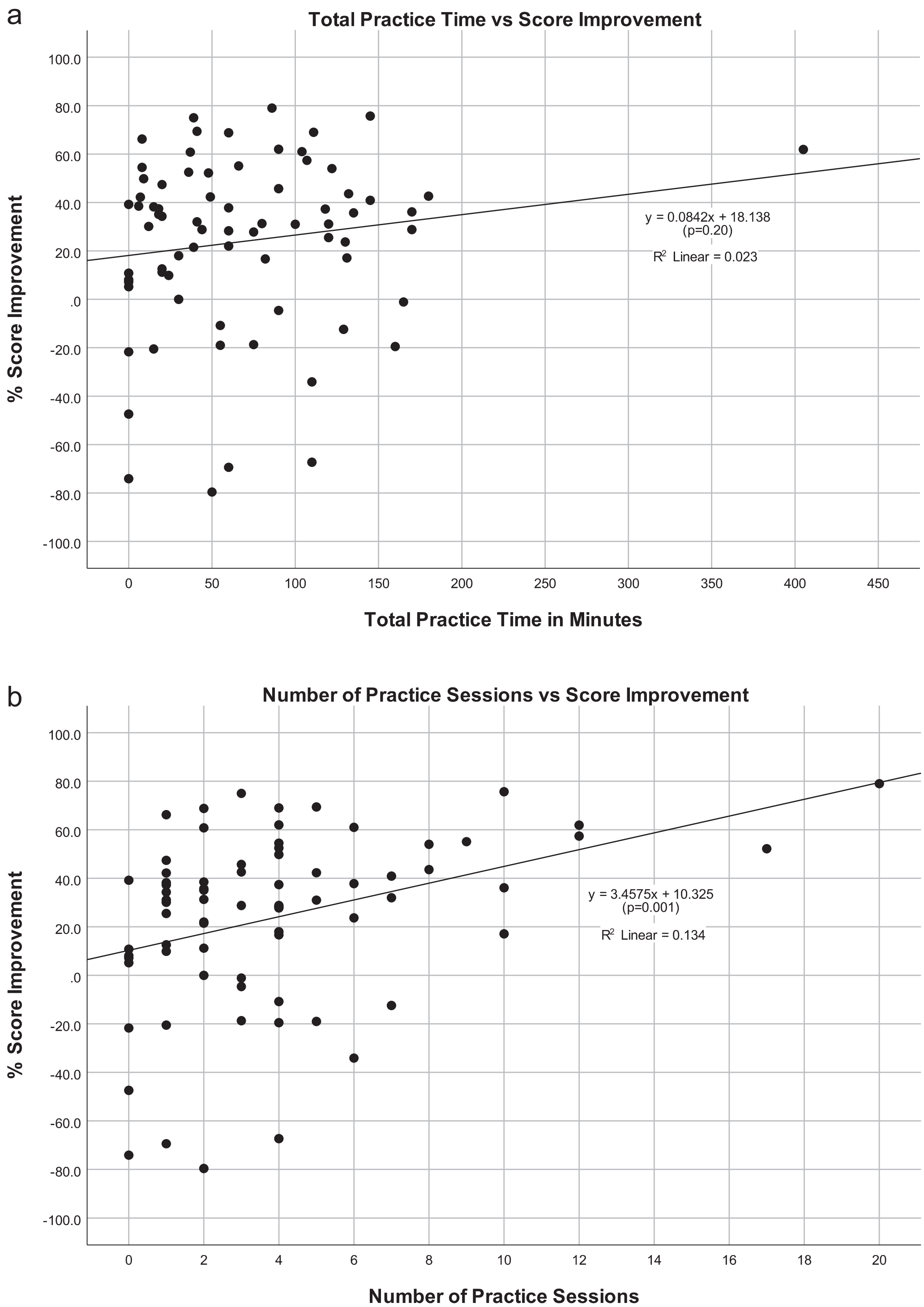

Fig. 2. Practice compared to score improvement.
a: Practice measured in minutes compared to score improvement.
b: Practice measured in session numbers compared to score improvement.

found both groups to improve significantly and that box training allowed for more practice sessions and less barriers to practice, however, there was a non-significant trend towards tower training being superior [15]. The mirror based box however is likely more difficult to work with compared to the camera based boxes, which are more similar to using a laparoscope, in our study and the above resident studies, which may account for the slight favoring of the laparoscopic video tower in their study. Given this, the above findings of the comparisons between simulation centers and home boxes in residents, and the fact that our students and PGY1 residents performed similarly, it is likely that home camera-based trainer boxes are just as effective in developing skills in medical students as simulation centers. Our finding that the number of training sessions but not the total time training correlated with improved scores also demonstrates that what was found in residents [13] is also true in medical students. When combined with findings that residents with home trainers practice more frequently [11], this suggests

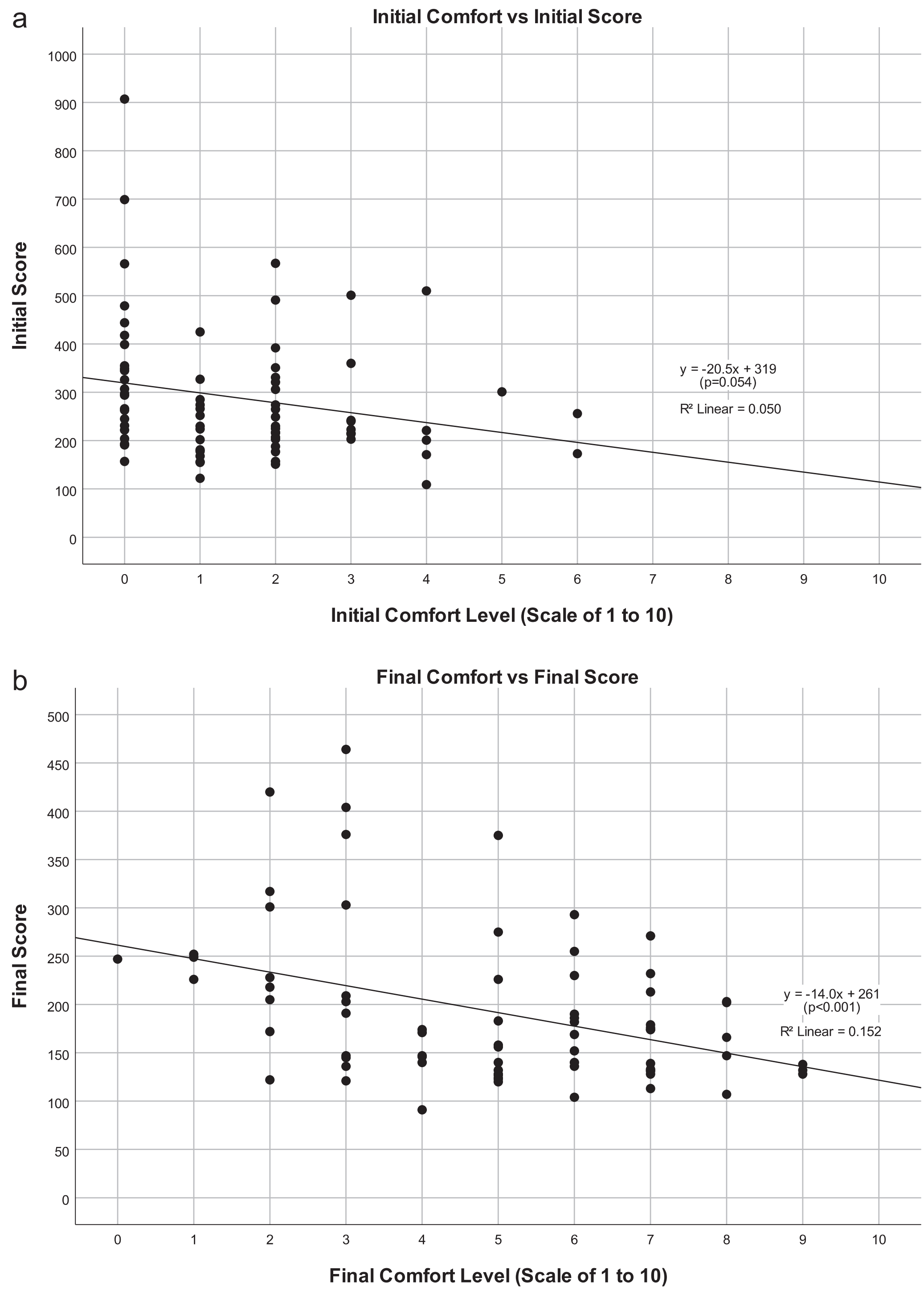

Fig. 3. Comfort with tasks compared to scores.
a: Initial comfort level compared to initial task score.
b: Final comfort level compared to final task score.

that home trainers may provide more opportunities for improvement over time.

The commercial trainer box used in our study is already relatively inexpensive at $375 compared to other commercially available boxes, but "do-it-yourself" boxes described by others have the potential to make this route of training even less expensive and more accessible to both resident physicians and medical students [5,14]. The combination of low cost equipment with a self-directed learning environment suggest that the home laparoscopic trainer box can easily be a standard part of OB/Gyn residencies starting the first year. It may also play a similarly prevalent role in medical school clerkships in the same way that surgical knot tying trainers have for years.

Self-directed training

Our study also demonstrates that improvements in laparoscopic skills can still be gained by providing home box trainers even in the absence of expert guidance or formal curriculum. Previous studies

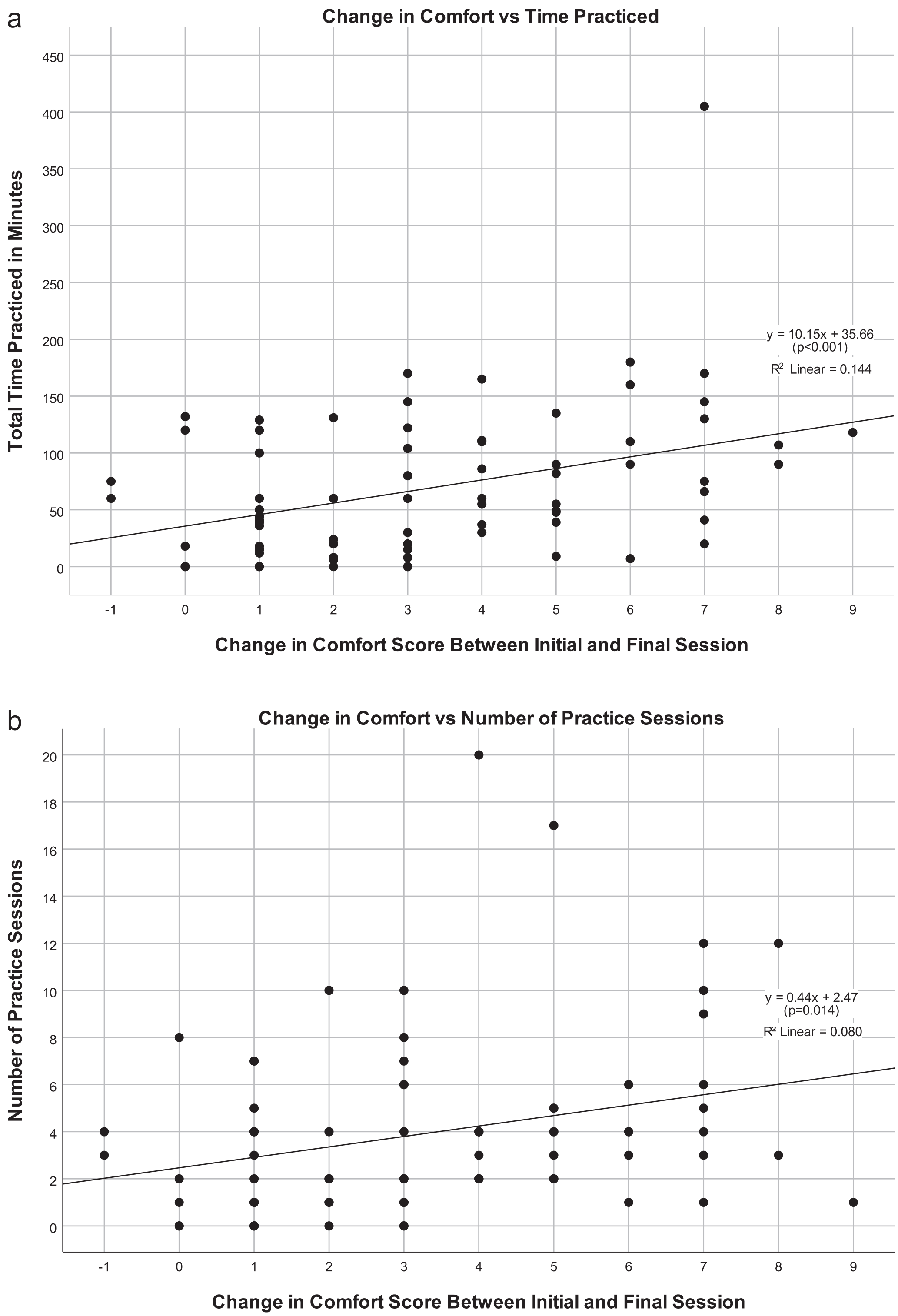

Fig. 4. Change in comfort level with laparoscopic tasks compared to practice.
a: Change in comfort level with laparoscopic tasks compared to minutes practiced.
b: Change in comfort level with laparoscopic tasks compared to number of practice sessions.

involved in person training courses, with the exception of Wilson's study, which had no training course but still provided video instructions. Wilson et al. demonstrated that having a remote supervisor made no difference in performance, suggesting that supervision was not necessary for improvement [12]. A study in 2014 by Gawad et al. also evaluated the role of instruction by comparing improvement in performance in 24 medical students after randomizing half of them to a training session with expert tutors providing active feedback, and the other half to a session with the same materials but no tutors, only video and simulator based instruction materials. They found no difference in scores between the two groups neither at the end of the training nor 5 weeks later with no additional training in between [7]. Both of these

Table 4
Surgical interest and relation to scores and practice.

	Initial score (seconds)	Final score (seconds)	Mean improvement %	Total practice time (minutes)	Number of practice sessions
No interest in surgical specialty or unsure ($n = 42$)	303 (SD = 153)	196 (SD = 79)	24.3 % (SD = 40.1)	76 (SD = 77)	4.3 (SD = 4.5)
Interest in surgical specialty or subspecialty ($n = 32$)	266 (SD = 109)	188 (SD = 80)	23.6 % (SD = 30.4)	61 (SD = 44)	3.5 (SD = 2.7)
Difference	37 ($p = 0.22$)	8 ($p = 0.68$)	0.7 % ($p = 0.93$)	15 ($p = 0.29$)	0.8 ($p = 0.34$)
No interest in surgical specialty or unsure, students ($n = 20$)	271 (SD = 110)	173 (SD = 60)	27.4 % (SD = 32.5)	111 (SD = 89)	6.6 (SD = 5.4)
Interest in surgical specialty or subspecialty, students ($n = 19$)	285 (SD = 122)	193 (SD = 93)	25.9 % (SD = 34.0)	67 (SD = 43)	3.8 (SD = 2.7)
Difference	14 ($p = 0.71$)	20 ($p = 0.42$)	1.5 % ($p = 0.89$)	44 ($p = 0.06$)	2.8 ($p = 0.0496$)*
General OB/Gyn or non-surgical fellowship, PGY1 residents ($n = 22$)	332 (SD = 181)	217 (SD = 89)	21.6 % (SD = 46.5)	44 (SD = 49)	2.2 (SD = 1.8)
Surgical fellowship, PGY1 residents ($n = 13$)	238 (SD = 82)	181 (SD = 58)	20.2 % (SD = 25.2)	52 (SD = 46)	3.1 (SD = 2.6)
Difference	94 ($p = 0.04$)*	36 ($p = 0.15$)	1.4 % ($p = 0.91$)	8 ($p = 0.63$)	0.9 ($p = 0.31$)

* $p < 0.05$.

studies suggest that self-directed training can be just as effective as guided training, but even in these studies the self-directed groups received video based instructions and curriculums whereas our study went one step further by providing no guidance on how to best complete the task at all. Participants in our study were free to seek out their own methods of guidance whether it be through simple trial and error from practicing, using resources found on the internet, or seeking out guidance from more senior OB/Gyn residents or attendings on their own. For the 7 participants that did seek out an instructor for at least one of their training sessions, there was no significant difference in scores, or improvement compared to the rest of the cohort. Our study demonstrates that medical students and PGY1 residents can develop laparoscopic skills and guide learning on their own without structured feedback or instruction. This finding is encouraging as more formal training takes up significantly more time and may not always be feasible, especially in a busy residency or a short OB/Gyn clerkship where a significant amount of teaching and experiences are already being packed into a brief period of time.

Comfort levels

When evaluating participant's comfort levels with laparoscopic tasks, we found a significant correlation between self-reported higher comfort levels and improved scores on the final task as well as significant correlations between improvement in comfort levels and more time practiced as well as higher number of practice sessions. This suggests that not only did scores objectively improve with practice, but participants' subjective comfort levels with the task also improved with more practice and a better comfort level was a predictor of a better score. We did not find any studies that directly reported on the relationship of subjective comfort levels with scores on a task, but a study by Nomura et al. [17] in 2018 did find that better self-perceived manual dexterity was related to better task scores and another study by Beattie et al. [18] in 2021 found that lower perceived demands involved in a novel and complex task resulted in better performance. While these findings are not the same as measuring comfort levels, they are similar in that they are self-reported subjective indicators of performance and thus support our finding that subjective self-reported measures such as comfort levels can be correlated with better performance and possibly be used as a surrogate measure to predict performance.

Interest in surgical specialties

One of the secondary aims of our study was to evaluate the effects of interest in a surgical specialty, or sub-specialty in the case of PGY1 residents, on performance and practice, as well as the impact the study had on participants' interest in the trainer and medical students' interest in surgery. Previous studies that examined the impact of surgical interest found that students' interest in becoming a surgeon did not impact their performance, though these studies did not evaluate the impact of interest on practice and did not involve the use of trainers at home [8,17]. Our study demonstrated that in the use of home trainers, interest in surgery still did not impact scores or improvement. Additionally, for the overall study, interest in surgery did not significantly impact the total time practiced or number of practice sessions, although in the sub-group of students there was a slight significant difference demonstrating that students who expressed interest in surgery practiced less than students who were unsure or interested in medicine. This finding was interesting as we expected that surgical interest would produce more interest in using the trainer and thus more practice. It is possible that this result occurred due to students who were unsure or interested in medicine using the study and the trainer as an opportunity to explore whether they might be interested in surgery whereas those confident in their desire to be a surgeon did not feel the need to spend as much time exploring. There is also likely an element of selection bias in this finding, as the voluntary nature of our study means that all the students who participated had some interest in using the laparoscopic trainer at baseline, and it is thus possible that other students not interested in surgery who did not participate in our study would not use the trainer as frequently had participation been required. Despite the potential bias, this result does demonstrate that there is utility in using laparoscopic home trainers in medical students even among those that do not have a current desire to pursue surgery as the amount of practice reflects interest in their use.

We did not find an increase in students deciding to go into a surgical field after participating in our study, but we also did not qualify the "unsure" responses. Studies involving medical students in laparoscopic training in the past have showed trends towards increases in interest in surgical fields after participating in training [7,19]. One study by Goldin et al. in 2012 evaluating factors that impact students matching into surgery also found that earlier exposure to surgery was related to students matching in surgery [20]. It is thus possible that the "unsure" students may have increased their interest in surgery after the study, just not to the point of being certain of their interest in a surgical field, and this combined with the findings of these other studies suggests that early exposure to laparoscopic home training in medical school may be beneficial to increasing interest in surgical fields. Students also directly expressed an interest in the training, with 67 % reporting they would practice regularly if given the trainer and 64 % reporting they wanted to keep the trainer longer by the end of the study. 94 % of PGY1 residents also expressed wanting to keep the trainer for longer, demonstrating a very strong interest in home laparoscopy training at the resident level. With multiple studies showing that students can retain their skills after training even after extended periods of not practicing [4–6] as well as

Table 5
Impact of participant characteristics and experiences on scores and improvement.

Characteristic	Initial score (seconds)	Final score (seconds)	Mean improvement %
Sex			
Male ($n = 22$)	272 (SD = 127)	175 (SD = 65)	24.5 % (SD = 35.9)
Female ($n = 52$)	294 (SD = 140)	200 (SD = 83)	23.8 % (SD = 36.3)
Difference	22 ($p = 0.53$)	25 ($p = 0.16$)	0.7 % ($p = 0.94$)
Past laparoscopy experience			
No past use of laparoscopic camera or instrument ($n = 28$)	311 (SD = 128)	193 (SD = 71)	33.1 % (SD = 22.9)
Past use of laparoscopic camera or instrument ($n = 46$)	273 (SD = 140)	192 (SD = 86)	18.5 % (SD = 41.3)
Difference	38 ($p = 0.23$)	1 ($p = 0.97$)	14.6 % ($p = 0.053$)
Handedness			
Left handed or ambidextrous ($n = 9$)	237 (SD = 94)	172 (SD = 60)	21.2 % (SD = 32.0)
Right handed ($n = 65$)	294 (SD = 140)	195 (SD = 81)	24.4 % (SD = 36.7)
Difference	57 ($p = 0.14$)	23 ($p = 0.31$)	3.2 % ($p = 0.79$)
Instructor use (among those who practiced at least once)			
No instructor use ($n = 59$)	293 (SD = 145)	186 (SD = 72)	26.7 % (SD = 35.4)
Instructor use at least once ($n = 7$)	306 (SD = 114)	179 (SD = 72)	39.4 % (SD = 15.7)
Difference	13 ($p = 0.79$)	7 ($p = 0.82$)	12.7 % ($p = 0.11$)
Task practiced (among those who practiced at least once)			
Peg task only ($n = 60$)	293 (SD = 144)	183 (SD = 71)	28.2 % (SD = 34.4)
Other task at least once ($n = 6$)	309 (SD = 118)	208 (SD = 80)	26.7 % (SD = 32.9)
Difference	16 ($p = 0.76$)	25 ($p = 0.50$)	1.5 % ($p = 0.92$)
Video game experience			
No frequent video game use ($n = 46$)	307 (SD = 150)	200 (SD = 86)	26.2 % (SD = 36.6)
Frequent video game use ($n = 28$)	255 (SD = 105)	179 (SD = 65)	20.4 % (SD = 35.3)
Difference	52 ($p = 0.09$)	21 ($p = 0.23$)	5.8 % ($p = 0.50$)
Musical instrument experience			
Does not play musical instrument ($n = 40$)	317 (SD = 157)	203 (SD = 79)	25.3 % (SD = 36.9)
Plays musical instrument ($n = 34$)	253 (SD = 91)	179 (SD = 75)	23.2 % (SD = 34.6)
Difference	64 ($p = 0.032$)*	24 ($p = 0.19$)	2.1 % ($p = 0.80$)
Competitive sport experience			
Does not play competitive sports ($n = 31$)	326 (SD = 164)	197 (SD = 87)	27.4 % (SD = 45.2)
Plays competitive sports ($n = 43$)	259 (SD = 105)	189 (SD = 73)	21.6 % (SD = 27.8)
Difference	67 ($p = 0.052$)	12 ($p = 0.66$)	5.8 % ($p = 0.53$)
Other fine hand motor skill hobbies			
Does not have other hobbies that involve fine hand motor skills ($n = 30$)	316 (SD = 179)	194 (SD = 84)	27.2 % (SD = 35.8)
Has other hobbies that involve fine hand motor skills ($n = 42$)	266 (SD = 91)	191 (SD = 76)	21.7 % (SD = 36.3)
Difference	50 ($p = 0.16$)	3 ($p = 0.87$)	5.5 % ($p = 0.52$)
Hobbies composite			
Has 0–1 hobbies involving motor skills ($n = 20$)	361 (SD = 190)	216 (SD = 95)	29.2 % (SD = 41.4)
Has 2+ hobbies involving motor skills ($n = 54$)	260 (SD = 99)	184 (SD = 71)	22.1 % (SD = 34.0)
Difference	101 ($p = 0.033$)*	32 ($p = 0.17$)	7.1 % ($p = 0.50$)

* $p < 0.05$.

studies showing potential for early exposure to surgery and integration of laparoscopic training into clerkships for increasing interest in surgical fields [7,19,20], it is important to start to make laparoscopic skills training a more integral part of undergraduate medical education.

Demographics and past experiences

The last set of secondary outcomes we looked at were the impact of different demographics, past experiences, and hobbies on participants' performances to evaluate if any of these variables could predict better laparoscopic skills. Past studies that have evaluated these variables have put focus on video games and musical instrument use and have given mixed results. Regarding video games, studies by Cavalini [8] and Nomura [17] with medical students found that video game use had no impact on task scores, while Abbas [19] found that it resulted in better baseline scores but did not result in better scores after training. A recent meta-analysis by Gupta et al. in 2021 did find that video game experience improved laparoscopy and robotic skills at baseline, but the studies they evaluated did not examine effects after laparoscopic training [21]. A study by Findeklee et al. in 2019 examined multiple variables including musical instrument use, sporting experience, handcrafts, and knitting and found no differences in laparoscopic knot tying over repeated tries in any of the variables examined, although a small sample size of 17 subjects precluded their ability to perform statistical analysis [22]. Our study found no statistically significant difference in initial or final scores from participants' age, sex, past student level laparoscopic experience, handedness, video game experience, competitive sport experience, and a category of “other” self-reported fine hand motor skill hobbies which included hobbies such as knitting, drawing, painting, car repairs, and baking. We did see significantly better initial scores in participants with musical instrument experience and in PGY1 residents interested in a surgical fellowship. We also found that having an increasing number of these hobbies correlated with improved initial score, but all these differences went away after practice with the trainer as there was no difference in the final scores for these groups. Except for video game use, where some larger studies have shown a baseline benefit, our study supports the current data with a larger sample size suggesting that these demographics and past experiences cannot predict laparoscopic skills. We additionally found that while playing musical instruments and having multiple hobbies may cause a lower baseline score, all participants level out after training, suggesting that none of these variables have any impact on laparoscopic skills once laparoscopic practice has taken place and thus no past experiences put individuals at an advantage when it comes to learning laparoscopic skills.

Strengths and limitations

Strengths of our study include being able a larger recruitment period, allowing more power to detect differences in our variables of interest. The participants were all naïve to laparoscopy, thus allowing a more accurate assessment of improvement in training and letting us better examine the effect of training with no curriculum or guidance as they did not have past experiences to influence the way the practiced or performed the task. We also intentionally provided no guidance, examples, or visual demonstrations on task technique in the initial live session to reduce bias for particular technique for completing the task, thus allowing for the potential to discover more efficient techniques as participants practiced on their own. The study demonstrates that participants were still able to improve with only self-directed learning. One major limitation of our study was the voluntary nature of participation, suggesting that all participants had at least some interest in laparoscopic surgery or training if they signed up, thus limiting the generalizability. Despite this, we still did have participants that did not practice with the trainer at all as well as students that were not interested in surgery who participated, thus allowing at least some inferences to be made about the utility of the trainers in a general medical student population. Another limitation of our study is the focus on a singular laparoscopic task for evaluation, thus making it unclear if our results would translate to other laparoscopic skills such as knot tying. We chose this partially to limit the equipment needed to take home and largely to allow the participants to focus their practice given the study period was a brief 3 weeks in the middle of already busy clerkship and residency schedules. We did however allow for practice with any other materials and exercises participants may have had access to at home, and in the participants that did so, there was no difference in scores and improvement suggesting that the skills are somewhat transferable. Future research is needed to explore the integration of home trainers into medical schools and early residency in a more standard fashion. Further studies could explore the impact of making the trainers a mandatory part of clerkship training instead of a voluntary one and evaluate the impact of that training on skills long term and with more training exercises.

Conclusions

Our study overall demonstrated that home laparoscopic trainers can be a useful tool in developing laparoscopic skills in surgically naïve trainees even in the absence of formalized laparoscopic teaching. These home trainers have the potential to help overcome time and access barriers to practice seen with traditional simulation centers. They allowed for more frequent practice sessions, which we showed correlated with better skills improvements. The combination of low-cost equipment, self-directed learning environment, and the level of interest all our participants expressed in using the trainer suggest that the home laparoscopic trainer box can easily be a standard part undergraduate medical education and OB/Gyn residencies starting the first year. Given these findings and the increasing importance of laparoscopy in surgery, home laparoscopy training should become a standard and integral part of medical school clerkships and early surgical field residencies. At our institution, we are already working towards providing home trainers to all OB/Gyn residents, as well as working laparoscopic trainers into the OB/Gyn clerkship, aiming to provide all students with a trainer to take home during their time on their OB/Gyn rotation.

CRediT authorship contribution statement

Eric G. Crihfield: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Pooja Uppalapati:** Formal analysis, Investigation, Data curation, Writing – review & editing. **Baruch Abittan:** Conceptualization, Methodology, Writing – review & editing. **Anya Laibangyang:** Investigation, Data curation. **Sonam Brahmbhatt:** Investigation, Data curation. **Madeleine Burlingame:** Investigation, Data curation. **Gary L. Goldberg:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Jill M. Rabin:** Conceptualization, Methodology, Writing – review & editing, Supervision.

Declaration of competing interest

Drs. Eric G. Crihfield, Pooja Uppalapati, Baruch Abittan, Anya Laibangyang, Sonam Brahmbhatt, Gary L. Goldberg, Jill M. Rabin, and Ms. Madeleine Burlingame have no conflicts of interest or financial ties to disclose.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Ethical approval

Study was approved by Northwell Health Institutional Review Board with ID #19-0230.

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