Training on an inexpensive tablet-based device is equally effective as on a standard laparoscopic box trainer

A randomized controlled trial

Eliana Montanari, MDa, Richard Schwameis, MDa, Marisa Louridas, MDa, Christian Göbl, MD, PhD, MScb,
Lorenz Kuessel, MDa, Stephan Polterauer, MDa, Heinrich Husslein, MD, PLLMa,∗

Abstract

Background: The aim of the study was to assess whether an inexpensive tablet-based box trainer (TBT) is at least equally effective compared with a standard box trainer (SBT) to learn basic laparoscopic skills (BLS). BLS training outside the operating room has been shown to be beneficial for surgical residency. However, simulation trainers are expensive and are not consistently available in all training centers. Therefore, TBT and other homemade box trainers were developed.

Methods: Medical students were randomized to either a TBT or an SBT and trained 4 fundamentals of laparoscopic surgery (FLS) tasks for 1 hour twice a week for 4 weeks. A baseline test before the training period and a posttraining test were performed. All students then completed a questionnaire to assess their assigned box trainer. The primary outcome measure was the improvement in total test scores. Improvement in the scores for the 4 individual FLS tasks was chosen as a secondary outcome measure.

Results: Thirty-two medical students were recruited. Baseline test scores did not differ significantly between the groups. BLS improved significantly in both groups for the total score and for all 4 tasks separately. Participants in the TBT group showed a greater improvement of total scores than those in the SBT group, although this did not reach statistical significance; noninferiority of the TBT compared with the SBT concerning the improvement of total scores could be demonstrated. Regarding the individual FLS tasks, noninferiority of the TBT could be shown for the pattern cutting and the suturing with intracorporeal knot-tying task. The acceptance of the TBT by the trainees was very good.

Conclusion: Learning BLS on a homemade TBT is at least equally effective as on an SBT, with the advantage of being very cost saving. Therefore, this readily available box trainer may be used as an effective, flexible training device outside the operating room to improve accessibility to simulation training.

Abbreviations: BLS = basic laparoscopic skill, FLS = fundamentals of laparoscopic surgery, IQR = interquartile range, OR = operating room, SBT = standard box trainer, SD = standard deviation, TBT = tablet-based box trainer.

Keywords: basic laparoscopic skill, box trainer, laparoscopy, surgical skills training, tablet-based laparoscopic box trainer

1. Introduction

Laparoscopic surgery has become the gold standard for many surgical procedures. In comparison with open surgery,

laporoscopic surgery requires a specific psychomotor skill set that may be more difficult to acquire, resulting in a prolonged learning curve. Due to residents spending less time in the operating room (OR), mainly as a result of work hour restrictions, difficulties have arisen in gaining enough surgical experience during training to reliably acquire sufficient laparoscopic skills. In order to overcome this problem, training of basic laparoscopic skills (BLS) outside the OR has gained increasing importance, and various simulation models have been developed to meet this need.

Numerous studies have shown that skills acquired in the simulation-environment transfer to the OR, and that simulation training programs significantly decrease the clinical learning curve. Although contemporary simulation training cannot replace clinical experience entirely, it allows trainees to make mistakes while practicing on a training model without compromising patient safety. Furthermore, it contributes to shorter operative times and reduces the risk of intra- and postoperative complications when trainees transition to the real OR.

Although the importance of simulation training is widely recognized and surgical bodies emphasize that training in a simulated environment should constitute an integral part of surgical residency, surgical skills laboratories are not consistently available across all training centers. For this reason,
many different types of low-cost homemade trainers have been developed. A particularly promising version consists of a cardboard box with an iPad serving as the camera and display (Fig. 1). Nowadays, tablets are owned by a considerable part of health care providers, especially residents. Therefore, nothing else but a cardboard box is necessary to construct this box trainer, which is particularly convincing since it is cheap and readily available everywhere in the world.

The aim of the present study was to investigate whether practicing on a homemade, inexpensive, tablet-based box trainer (TBT) is at least equally effective compared with the use of a traditional box trainer in improving BLS.

2. Materials and methods

2.1. Study design

This randomized controlled trial (ClinicalTrials.gov ID: NCT02491710) was conducted at the Surgical Skills Training Center in the Department of Obstetrics and Gynecology at the Medical University of Vienna. The study started August 2015 and ended September 2015. Participants were randomized to 1 of the following 2 groups: training on a homemade tablet-based cardboard box trainer (TBT) or training on a standard box trainer (SBT).

2.2. Participants

Medical students were recruited from the Medical University of Vienna. Medical students with limited experience in laparoscopic surgery were eligible. Students were excluded if they had performed any laparoscopic operation as the primary surgeon or had regular (e.g., once per month) practice on a box trainer for the last 12 months.

Written informed consent was obtained from all participants prior to the start of the study. A unique study identification number was assigned to each participant and baseline demographic data were collected using a paper questionnaire at the time of consent. Approval for this study was obtained from the Ethics Committee of the Medical University of Vienna (IRB approval number: 1322/2015).

2.3. Interventions

Training sessions took place twice a week for 4 weeks with each training session lasting a maximum of 1 hour. Participants performed the following 4 fundamentals of laparoscopic surgery (FLS) tasks: peg transfer, pattern cutting, suturing with extracorporeal knot tying, and suturing with intracorporeal knot tying. At the beginning of the study, prior to the first training session, an instruction video demonstrating the 4 FLS tasks was shown to all participants, followed by a baseline test for each of the 4 tasks. During the training sessions, surgical instructors were present to provide feedback and supervise the participants. Participants were asked to complete at least 10 repetitions of the peg transfer task and the pattern cutting task, whereas for both suturing tasks participants were instructed to practice until a self-perceived improvement was noted, with a maximum overall time limit of 1 hour for each training session. Every training session consisted of 2 of the 4 tasks, of which one was a suturing task. At the end of the study, each participant performed a posttraining test, identical to the baseline test.

2.3.1. Training on an inexpensive TBT. During the study period, participants randomized to the TBT group performed the 4 FLS tasks on a box trainer consisting of an Apple iPad 6 (Apple Inc., Cupertino, CA) placed over a hole cut into the upper part of a cardboard box (Fig. 1), which was constructed as previously described. The iPad was used on the video recording function with the auto-snooze and auto-focus functions turned off during the exercises.

2.3.2. Training on an SBT. Participants randomized to the SBT group practiced on the LaproTrain box trainer (Endosim, Belfast, Northern Ireland) consisting of a box with a self-holding camera connected to a separate color video monitor (Grundig, Nürnberg, Germany) (Fig. 2).

2.4. Outcome measures

2.4.1. Baseline and posttraining assessment. The baseline and the posttraining assessment were completed by each participant performing each of the 4 FLS tasks once. A WISAP Simulation Trainer (WISAP Medical Technology, Brunenthal, Germany) (Fig. 3) was used together with a camera head (Karl Storz, Tuttlingen, Germany), a 300 W Xenon light source (Karl Storz), a 10 mm 0° laparoscope (Karl Storz) and a color video camera.
monitor (Sony, Tokyo, Japan). For both the baseline and the posttraining test, participants were allowed to become familiar with this type of box trainer by performing half of the first task (peg transfer) once prior to the assessment.

2.4.2. Primary outcome measure. Performance of the 4 FLS tasks was assessed according to the time needed to complete the task as well as the accuracy of task performance using the FLS scoring system as previously described. A staff surgeon, proficient in laparoscopy and with significant experience in surgical training using the FLS tasks, carried out the assessment. The improvement of performance for the total score as well as for each FLS task was calculated by subtracting the baseline test scores from the posttraining test scores. The primary outcome measure was the improvement in total test scores.

2.4.3. Secondary outcome measures. In addition to the total test scores, improvement in the scores for the 4 individual FLS tasks was chosen as a secondary outcome measure. Furthermore, at the end of the study, participants were asked to complete a questionnaire (see Supplemental Content, http://links.lww.com/MD/B302) regarding the quality and usefulness of the box trainer they had practiced on during the study. Lastly, after completion of the study participants performed each of the 4 FLS tasks on the other type of box trainer once (i.e., participants randomized to the SBT group used the TBT and vice versa), and were asked to indicate whether they would have preferred to practice on this type of box trainer instead of the box trainer they were randomized to.

2.5. Sample size calculation
Sample size calculation was performed for a noninferiority trial with a continuous outcome. We considered a noninferiority margin of 10% of the mean improvement in total scores after training of the control group (i.e., the SBT group) to be the minimum clinically significant difference and calculated the required sample size applying a single-tailed \( \alpha \) of 0.025 and a power of 0.90. Calculation was based on the previous results for the FLS tasks of novice trainees showing a mean improvement in total scores of 342 points with a standard deviation (SD) of 24 points. These are the best available data given the absence of other trials, or sufficient published data to calculate a correlation coefficient of absolute scores and SDs that could be used to impute the SD of change improvement. According to the considerations made above, 12 participants were required in each training arm. Anticipating a drop out rate of 20%, a minimum of 15 participants had to be included per study group.

2.6. Randomization and masking
For randomization, an allocation ratio to each treatment of 1:1 was used. Participants were randomized according to the concealed sequence of a computer-generated randomization plan by one of the research team members. Participants were consecutively randomized into 1 of the 2 groups by means of sealed envelope technique. No masking was used, because the FLS scoring system is standardized and objective.

2.7. Statistical analysis
Data was analyzed according to the intention-to-treat principle. Diagrams were used to assess normality of the distributions. For data not following a normal distribution, nonparametric tests were performed, using the Mann–Whitney U test for comparisons between groups and the Wilcoxon signed-rank test for comparisons within groups. For normally distributed data, Welch’s t test for independent samples was used for comparisons between groups. Medians and interquartile ranges (IQRs) or means and SDs, respectively, are shown for continuous and ordinal data. Nominal data were analyzed by the Fisher exact test. Two-sided \( P < 0.05 \) were considered statistically significant. For the analysis of the primary outcome (i.e., improvement in total test scores) as well as of the improvement in the scores for the individual tasks, noninferiority was determined if the lower bound of the 2-sided 95% confidence interval (according to the Welch’s t test) of the mean difference in improvements did not
Table 1
Baseline demographic data of SBT and TBT groups.

|                          | SBT (n=16) | TBT (n=16) | P      |
|--------------------------|------------|------------|--------|
| Age [years], median (IQR)| 24.5 (23–26.75) | 25 (23–26.75) | 0.93   |
| Year of medical studies [years], median (IQR) | 6 (2.5–6) | 4.5 (3–6) | 0.49   |
| Sex, female:male          | 10:6       | 12:4       | 0.70   |
| Handedness, right:left    | 14:2       | 14:2       | >0.99  |
| Assisted in laparoscopic operations, yes:no | 10:6 | 11:5 | >0.99 |
| Simulation training experience, yes:no | 2:14 | 4:12 | 0.65  |
| Video game experience, yes:no | 9:7 | 7:9 | 0.72  |
| Played a musical instrument, yes:no | 10:6 | 9:7 | >0.99 |

IQR = interquartile range, SBT = standard box trainer group, TBT = tablet-based box trainer group. Mann–Whitney U test was used for comparisons of continuous and ordinal data. Nominal data was compared using the Fisher exact test. P < 0.05 were considered statistically significant.

-exceed the noninferiority margin (i.e., 10% of the mean improvement in the SBT group). IBM SPSS version 21.0 (IBM Corp., Armonk, NY) was used for statistical analysis.

3. Results

3.1. Participants

Thirty-two medical students were recruited and randomized to either the SBT (n = 16) or the TBT (n = 16) group. All participants completed the study and were included in the final analysis. Baseline demographic data of the participants are shown in Table 1. There were no significant differences between groups regarding age, year of medical school, sex, handedness, having assisted in laparoscopic operations, simulation training experience, video game experience, or playing a musical instrument.

3.2. Primary outcome measure: improvement in total scores

There were no statistically significant differences in the baseline test scores between the SBT and the TBT group for the total scores (Table 2). Both in the SBT and in the TBT group, a significant improvement between baseline and posttraining total test scores was demonstrated (Table 2). Total score improvement was found to be greater in the TBT group than in the SBT group, although this difference did not reach statistical significance (Table 3). Noninferiority regarding the total score improvement in the TBT group could be shown (Table 3). For the posttraining total test scores, there was again a trend toward higher posttraining scores in the TBT group compared with the SBT group, although this did not reach statistical significance (Table 2).

3.3. Secondary outcome measure: improvement in the scores for the individual FLS tasks

There were no statistically significant differences in the baseline test scores between the SBT and the TBT group for the 4 individual FLS tasks (peg transfer, pattern cutting, suturing with extracorporeal knot tying, and suturing with intracorporeal knot tying) (Table 2). Both in the SBT and in the TBT group, a significant improvement between baseline test scores and

|                          | SBT median (IQR) | TBT median (IQR) | P (between groups) |
|--------------------------|------------------|------------------|--------------------|
| Total score              |                  |                  |                    |
| Baseline test score      | 63.8 (41.7–80.6) | 50.0 (6.7–100.1) | 0.42               |
| Posttraining test score  | 265.2 (252.2–298.0) | 308.0 (252.6–316.2) | 0.056              |
| P (within the group)     | <0.001*          | <0.001*          |                    |
| Peg transfer             |                  |                  |                    |
| Baseline test score      | 5.6 (0–21.1)    | 0 (0–7.7)       | 0.31               |
| Posttraining test score  | 74.8 (69.2–82.7) | 71.8 (60.5–79.9) | 0.75               |
| P (within the group)     | <0.001*          | <0.001*          |                    |
| Pattern cutting          |                  |                  |                    |
| Baseline test score      | 24.8 (14.0–35.4) | 8.35 (0.5–36.6)  | 0.42               |
| Posttraining test score  | 68.8 (64.7–74.3) | 73.6 (66.9–76.8) | 0.24               |
| P (within the group)     | <0.001*          | <0.001*          |                    |
| Suturing with extracorporeal ECknot |            |                  |                    |
| Baseline test score      | 13.2 (0–29.4)   | 0 (0–40.4)      | 0.70               |
| Posttraining test score  | 79.1 (64.4–89.9) | 84.9 (64.7–95.4) | 0.27               |
| P (within the group)     | 0.001*           | 0.001*           |                    |
| Suturing with intracorporeal ICknot |             |                  |                    |
| Baseline test score      | 0 (0–26.7)     | 0.5 (0–33.6)    | 0.52               |
| Posttraining test score  | 54.2 (49.0–71.1) | 73.1 (60.0–83.1) | 0.011*             |
| P (within the group)     | <0.001*          | <0.001*          |                    |

EC = extracorporeal knot, IC = intracorporeal knot, IQR = interquartile range, SBT = standard box trainer group, TBT = tablet-based box trainer group. The Wilcoxon signed-rank test was used for comparisons within groups; the Mann–Whitney U test was performed for comparisons between groups.

* Statistically significant values (P < 0.05).
Comparision of the score improvements for the total scores and the different FLS tasks between groups.

| Task                  | SBT mean ± SD | TBT mean ± SD | P     | NIM (–) [pts] | 95% CI       |
|-----------------------|---------------|---------------|-------|---------------|--------------|
| Total score           | 200.1 ± 20.5  | 233.4 ± 60.5  | 0.052 | –20.0         | –0.3 to 66.8 |
| Peg transfer          | 59.0 ± 18.1   | 62.6 ± 16.6   | 0.56  | –5.9          | –8.9 to 16.1 |
| Pattern cutting       | 43.0 ± 13.9   | 52.5 ± 18.7   | 0.12  | –4.3          | –2.5 to 21.4 |
| Suturing with EC      | 54.0 ± 31.3   | 62.9 ± 29.6   | 0.42  | –5.4          | –13.1 to 30.9|
| Suturing with IC      | 44.1 ± 12.9   | 55.5 ± 23.5   | 0.10  | –4.4          | –2.5 to 25.2 |

CI = confidence interval, EC = extracorporeal knot, IC = intracorporeal knot, NIM = noninferiority margin, pts = points, SBT = standard box trainer group, SD = standard deviation, TBT = tablet-based box trainer group. The improvement in test scores was calculated as the difference between post training test scores and baseline test scores. P values and 2-sided 95% CIs for the Welch’s t-test for independent samples are given.

Noninferiority of the TBT compared to the SBT was shown.

3.4. Secondary outcome measure: comfort and satisfaction with the assigned box trainer

There were no statistically significant differences in the evaluation of visibility, posture comfort, effectiveness as a laparoscopic box trainer, and overall satisfaction with the assigned box trainer on a 10-point visual analog scale between the SBT and the TBT group. The lighting conditions were perceived to be better in the SBT group than in the TBT group (SBT group: median 9, IQR 8–9.75, TBT group: median 7, IQR 6–8.75; P = 0.015, Mann–Whitney U test), whereas the image sharpness was rated better in the TBT than in the SBT group (SBT group: median 6.5, IQR 4.5–7, TBT group: median 8.5, IQR 8–9; P = 0.005, Mann–Whitney U test). There was no statistically significant difference in the proportion of participants who would have preferred practicing on the type of box trainer of the other group instead of the box trainer they were assigned to (2/16 in the SBT group versus 6/16 in the TBT group, P = 0.22, Fisher exact test).

4. Discussion

4.1. Improvement of BLS

We performed a randomized controlled trial to assess whether training of BLS on a homemade TBT is at least equally effective compared with an SBT. After a training period of 4 weeks, a significant improvement of skills was observed in both study groups, irrespective of the type of box trainer that was used. Noninferiority of the TBT compared with the SBT could be shown for the improvement in total test scores, as well as for the improvement in the scores of the pattern cutting and the suturing with intracorporeal knot-tying task. For the suturing with intracorporeal knot-tying task, participants in the TBT group showed statistically significantly higher posttraining scores than those in the SBT group. No significant difference in posttraining test scores was observed between the 2 groups for the other 3 tasks studied. For all tasks including total scores, a trend toward a greater improvement in the TBT group than in the SBT group could be seen.

These results suggest that an inexpensive, homemade TBT can be considered to be at least equally effective compared with an SBT in terms of training of BLS, while having the great advantage of being readily available for everyone and very cost saving. The SBTs used in this study were purchased for 4890 € each (without monitor), while the homemade TBT, which can be built by simply “recycling” a cardboard box, was free of cost except for the iPad or tablet. Beyond the great cost savings, the TBT is also very space saving and offers the advantage of considerable flexibility concerning training location, as it is very light and has no need for an external light source or a monitor to be connected to. Furthermore, as opposed to the SBT, no power outlets or cables are necessary for the TBT, adding to the flexibility. Therefore, it represents an easily accessible, flexible, cost saving, and effective training alternative outside the OR.

4.2. Laparoscopic skills training outside the OR

It has been repeatedly demonstrated that the skills acquired by simulation training transfer to the OR and decrease operative times, intra- and postoperative complications.[7–12] Despite the widely recognized importance of simulation training, adequate training opportunities are not consistently available across training centers. For example, only about one-third of the respondents of a survey among gynecology, urology, and general surgery residents in Belgium had the facilities to implement deliberate practice in simulation skills laboratories.[24] Interestingly, even residents in programs with access to a skills laboratory often made limited use of this resource due to restrictive opening hours or inconvenient location of the training facilities.[25] In the Netherlands, a survey found that 55% of all gynecological teaching hospitals did not offer simulation training at all.[27] and a survey encompassing 32 different European countries reported that 42% of the residents did not have access to a simulation training facility.[28]

In order to overcome these difficulties, trainees may consider practicing on a self-made box trainer at home or in the hospital (e.g., on-call room). Homemade box trainers allow training without any constraints regarding availability, location or opening hours of surgical skills laboratories. To date different low-cost box trainers have been developed.[14–21] Previous randomized controlled trials comparing low-cost box trainers to SBT reported similar results to those found in this study. However, the available trials had flaws regarding the study design and methodology, therefore limiting their reliability and generalizability. Some of these limitations include not making use of a neutral box trainer for the assessment of task perfor-
mance,

suture with extracorporeal knot tying, and suture with intracorporeal knot tying, to evaluate different levels of task difficulty. The fifth FLS task, the ligating loop task, was recently found to have poor discriminatory ability and was therefore not included.

Based on the knowledge from previous studies that demonstrated skill retention is superior using a distributed training model (i.e., practice interspersed with periods of rest) compared with mass training model (continuous practice with little or no rest in between practice sessions), the training sessions in this trial were limited to 1 hour each and offered twice a week for a 1 month time period.

In order to avoid a possible advantage of 1 group over the other at the time of the posttraining test due to habituation to a particular type of box trainer, both the baseline and the posttraining test were performed on a third, neutral box trainer.

4.6. Limitations

This trial has some limitations. First, the use of a tablet for visualization does not allow for training on camera navigation, which is an essential skill in laparoscopic surgery. However, in addition to the availability of simple and low-cost simulation methods, teaching camera navigation in the OR is less problematic, as it does not represent a direct threat to the patient.

Furthermore, it could be argued that tablets are expensive and not everyone has one. However, to over the last decade the prevalence of tablets in medicine has sharply increased. Nowadays, iPads or other tablets are owned by a considerable proportion of medical institutions and health care providers, especially residents. In addition, tablets are becoming more integrated into clinical practice and medical education, with a continuous development of new applications. Furthermore, low-cost tablets have become available in recent years, which will likely further augment this trend.

5. Conclusion

An inexpensive, homemade, tablet-based laparoscopic box trainer appears to be equally effective compared with an SBT in terms of BLS acquisition and is well accepted by trainees. The type of box trainer tested offers an effective, very cost saving and flexible opportunity for students and residents to train and improve their skills outside the OR without compromising patients’ safety. Considering the very low cost compared with a SBT, this concept represents a promising method to promote acquisition of technical skills outside the OR in surgical training programs with limited availability and access to simulation centers.

Acknowledgments

The authors thank Olympus for providing the needle holders and knot pushers used in this study.

References

[1] Ward NT, Ramamoorthy SL, Chang DC, et al. Laparoscopic appendectomy is safer than open appendectomy in an elderly population. JLS 2014;18.
[2] Watson DI, Mathew G, Williams JA. Impact of laparoscopic cholecystectomy in a major teaching hospital: clinical and hospital outcomes. Med J Aust 1995;163:527–30.
[3] Cox TC, Huntington CR, Blair LJ, et al. Laparoscopic appendectomy and cholecystectomy versus open: a study in 1999 pregnant patients. Surg Endosc 2016;30:593–602.
[4] Derossis AM, Fried GM, Abrahamowicz M, et al. Development of a model for training and evaluation of laparoscopic skills. Am J Surg 1998;175:482–7.

[5] Moss EL, Bredaki FE, Jones PW, et al. Is gynaecological surgical training a cause for concern? A questionnaire survey of trainees and trainers. BMC Med Educ 2011;11:32.

[6] Palter VN, Grantcharov TP. Simulation in surgical education. CMAJ 2010;182:1191–6.

[7] Dawe SR, Pena GN, Windsor JA, et al. Systematic review of skills transfer after surgical simulation-based training. Br J Surg 2014;101:1063–76.

[8] Palter VN, Örzech N, Remick RK, et al. Validation of a structured training and assessment curriculum for technical skill acquisition in minimally invasive surgery: a randomized controlled trial. Ann Surg 2013;257:224–30.

[9] Larsen CR, Soerensen JL, Grantcharov TP, et al. Effect of virtual reality training on laparoscopic surgery: randomised controlled trial. BMJ 2009;338:b1802.

[10] Grantcharov TP, Kristiansen VB, Bendix J, et al. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. Br J Surg 2004;91:146–50.

[11] Seymour NE, Gallagher AG, Roman SA, et al. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. Ann Surg 2002;236:458–63.

[12] Willaert W, Van De Putte D, Van Renterghem K, et al. Training models for laparoscopic surgical training: examination of a low-cost alternative. Eur Urol 2006;50:1285–90. 1290–91.

[13] Aggarwal R, Moorothy K, Darzi A. Laparoscopic skills training and assessment. Br J Surg 2004;91:1549–53.

[14] Blacker AJ. How to build your own laparoscopic trainer. J Endourol 2005;19:749–52.

[15] Khine M, Leung E, Morran C, et al. Homemaded laparoscopic simulators for surgical trainees. Clin Teach 2011;8:118–21.

[16] Walczak DA, Piotrowski P, Jedrzejczyk A, et al. A laparoscopic simulator: maybe it is worth making it yourself. Wideochir Inne Tech Maloinwazyjne 2014;9:380–6.

[17] Sharpe BA, MacHaidz Z, Ogan K. Randomized comparison of standard laparoscopic trainer to novel, at-home, low-cost, camera-less laparoscopic trainer. Urology 2005;66:50–4.

[18] Jaber N. The basket trainer: a homemade laparoscopic trainer attainable to every resident. J Minim Access Surg 2010;6:3–5.

[19] Chung SY, Landsittel D, Chon CH, et al. Laparoscopic skills training using a webcam trainer. J Urol 2005;173:180–3.

[20] Polkorny MR, McLaren SL. Inexpensive homemade laparoscopic trainer and camera. ANZ J Surg 2004;74:691–3.

[21] Beatty JD. How to build an inexpensive laparoscopic webcam-based trainer. BJU Int 2005;96:679–82.

[22] Ruparel RK, Brahmbhatt RD, Dove JC, et al. ‘Trainers’: novel and inexpensive alternatives to traditional laparoscopic box trainers. Urology 2014;83:116–20.

[23] Sclafani J, Tittel TF, Franko OL. Mobile tablet use among academic physicians and trainees. J Med Syst 2013;37:9903.

[24] Polterauer S, Grimm C, Hanzl E, et al. Surgical skills training: results of a prospective trial. Geburtshilfe Frauenheilkd 2010;70:990–3.

[25] Scott DJ, Ritter EM, Tesfay ST, et al. Certification pass rate of 100% for fundamentals of laparoscopic surgery skills after proficiency-based training. Surg Endosc 2008;18:877–93.

[26] De Win G, Everaerts W, De Ridder D, et al. Laparoscopy training in Belgium: results from a nationwide survey, in urology, gynecology, and general surgery residents. Adv Med Educ Pract 2013;6:55–63.

[27] Kolkmann W, Wolterbeek R, Jansen F. Gynecological laparoscopy in residency training program: Dutch perspectives. Surg Endosc 2005;19:1498–502.

[28] Furriel FT, Laguna MP, Figueiredo AJ, et al. Training of European urology residents in laparoscopy: results of a pan-European survey. BJU Int 2013;112:1223–8.

[29] Chandrasekera SK, Donohue JF, Orley D, et al. Basic laparoscopic surgical training: examination of a low-cost alternative. Eur Urol 2006;50:1285–90. 1290–1291.

[30] Nakamura LY, Martin GL, Fox JC, et al. Comparing the portable laparoscopic trainer with a standardized trainer in surgically naive subjects. J Endourol 2012;26:67–72.

[31] Ženeldis B, Ruparel RK, Cook DA. Validity evidence for the fundamentals of laparoscopic surgery (FLS) program as an assessment tool: a systematic review. Surg Endosc 2016;30:512–20.

[32] Zheng B, Hur HC, Johnson S, et al. Validity of using fundamentals of laparoscopic surgery (FLS) program to assess laparoscopic competence for gynecologists. Surg Endosc 2010;24:132–61.

[33] Sroka G, Feldman LS, Vassiliou MC, et al. Fundamentals of laparoscopic surgery simulator training to proficiency improves laparoscopic performance in the operating room: a randomized controlled trial. Am J Surg 2010;199:115–20.

[34] Moulton CA, Dubrowski A, Macrae H, et al. Teaching surgical skills: what kind of practice makes perfect?: a randomized, controlled trial. Ann Surg 2006;244:400–9.

[35] Lumsden CJ, Byrne-Davis LM, Mooney JS, et al. Using mobile devices for teaching and learning in clinical medicine. Arch Dis Child Educ Pract Ed 2015;100:244–51.