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ORIGINAL ARTICLE

Unsupervised use of laparoscopic box trainers in a cohort of UK core surgical trainees

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Abstract

Background: Laparoscopic box trainers have been shown to improve acquisition of skills transferable to the operating theatre. However, despite calls for take-home box trainers to be made widely available, the effectiveness of unsupervised use is unknown. The aim of this study was to identify differences in task performance between surgical trainees allocated a take-home box trainer compared with controls. **Methods:** Thirty trainees at the beginning of their core surgical training (CST) were randomly allocated to control or intervention groups. A transfer task and a shape-cutting task were assessed according to the previously validated MISTELS system. Data were collected at the start and end of year one. The difference between pre- and post-study performance of each task was calculated. A survey was also undertaken to evaluate the use of the box trainers. **Results:** For the transfer task, the means of the differences between trainees' pre- and post-study performance scores for the control and intervention groups were 60.9 and 106.1, respectively ($P = 0.041$). For the shape-cutting task, the means of the differences between trainees' pre- and post-study performance scores for the control and intervention groups were 7.6 and 4.8, respectively ($P = 0.912$). Only 12% of survey respondents used the box trainer once a month or more, however 65% rated it as sometimes helpful or very helpful. **Conclusions:** In this study, unsupervised use of the box trainer was associated with improvement in a simple transfer task, but incorporation into a supervised laparoscopic training curriculum may be required for more complex tasks.

Keywords: *Laparoscopy; simulation; training; surgical skills; portable simulation; education*

Introduction

Laparoscopic simulation has developed in response to the challenges of modern surgical training, which include patient safety concerns and reduced trainee exposure to operative cases. There is evidence that the estimated annual number of operative training opportunities for core surgical training (CST) equivalent trainees fell by 30% between 2000 and 2006.[1]

Laparoscopic simulators vary in design from simple box trainers to those combining virtual reality (VR) technology with haptic feedback and performance assessment software. Those using VR technology have potentially higher fidelity, particularly if combined with haptic feedback. However, they are more expensive and therefore tend to be centralized in fewer centres.[2] Box trainers tend to have lower fidelity but use haptic feedback by definition and are less costly, enabling more widespread distribution.

Development of different simulators has been accompanied by an increasing volume of associated research. VR simulators have been found to be effective in reducing the learning curve for procedures before direct operative exposure.[3] Box trainers have been found to improve acquisition of skills transferable to the operating theatre.[4] A Cochrane meta-analysis of randomized controlled trials on the effectiveness of VR training for laparoscopic surgery concluded that both VR and box trainer simulator training decreased the time taken to perform a task and decreased errors.[5]

Although research shows benefit from the use of these simulators, their effectiveness may be limited by access issues. A study of international surgeons reported that only 34% had access to simulators.[6] A survey of UK gynaecologists demonstrated that only 14.6% had a VR simulator in their hospital, but at least 63% had access to a laparoscopic box trainer.[2] However, several studies have found that even when resources are available, they are often under-utilized.[7,8] The reasons for this under-utilization are not fully understood although lack of time and poor incentivisation have been suggested.[6] Affordable take-home box trainers have been suggested as one solution to these problems. There is evidence that distributed practice is better than massed practice in learning laparoscopic skills,[9,10] and this may be easier to achieve with take-home box trainers. Monitoring feedback and high-quality graphics are not usually available with box trainers, therefore they have traditionally been used with expert supervisors on hand to give feedback on performance.[11] There is, however, some evidence that this model of regular feedback is not mandatory for improvement of performance in laparoscopic simulation.[12] The question of whether trainee-driven unsupervised practice with take-home box trainers is beneficial for improvement of laparoscopic skills must be explored in order to ensure that the provision of laparoscopic simulation training is optimized.

This study was designed to determine whether a take-home laparoscopic box trainer improved the acquisition of basic skills in a cohort of core surgical trainees undertaking self-directed skills practice.

Methods

Participants and assessment schedule

All Severn Deanery trainees at the beginning of their first year of CST were invited to participate. Core surgical trainees within the UK surgical training system undertake 2 years of clinical experience after graduation from university as a medically qualified doctor. CST consists of a 2-year programme of posts in a variety of surgical specialties.

Trainees were randomized into a control group and an intervention group using simple manual random sampling by an independent blinded facilitator. Group allocation was not revealed to participants until after the baseline assessment tasks had been completed. Before baseline assessment, the tasks were explained and demonstrated to the trainees (see below). The explanation was reinforced with written guidance. A baseline assessment was video-recorded after a 5-min warm-up period during which they familiarized themselves with the equipment and the task. After the baseline assessments were completed, only trainees randomized to the intervention group received a box trainer to allow independent unsupervised practice over the subsequent 12 months.

A final assessment of all participants was carried out after 12 months. This was performed in the same way as the baseline assessment.

Pre-study survey and training log

We recorded the placement information for all trainees during year 1 of CST. In addition, all trainees were asked to log their operating and simulation experience over the study period. Trainees from either group were not prohibited from using any other simulators or participating in simulation opportunities that they were offered during the course of their CST training.

We assessed basic skills that are transferable to other types of minimally invasive surgery (MIS), such as arthroscopy or cystoscopy. We conducted an anonymized survey of the participants on the day of the initial assessment to ascertain whether trainees believed that MIS would form an important part of their workload as a consultant.

Ethical considerations

When invited to participate, it was made clear to trainees that those randomized to the control group would receive a box trainer to use for the duration of their core training after the study period (at the end of year 1) after they presented for their second assessment. Ethical approval was discussed with Local Research Ethics Committees at the time the study was being planned (2011). There was educational equipoise regarding the utility of the trainers and ethical approval for the study was judged not required as the research did not affect patient care. Explicit signed consent was given by the participants in line with the Declaration of Helsinki guidance.

Box trainer description

The Ethicon Endosurgery Task-it box trainer consists of a collapsible fabric box (40 × 28 × 18 cm) with six port-site holes in the top, which is open at one end to allow the webcam to be used. A pegboard (40 × 28 cm) placed in the bottom of the fabric box holds the tasks and a webcam links to a personal computer or laptop (Fig. 1). The fabric box, pegboard and webcam fit into a laptop-sized bag for easy transportation.

Tasks

Tasks were adapted from the MISTELS system (McGill Inanimate System for Training and Evaluation of Laparoscopic Skills), which consists of seven standardized tasks performed on a box trainer. The tasks and their

Figure 1. Box trainer in situ.

Figure 2. Polo mint as used in the transfer task.

assessment are easily reproducible.[13] Four of the seven tasks in the MISTELS system have individual construct validity (pegboard transfer, shape-cutting, extracorporeal knot tying and intracorporeal knot tying) and were therefore considered for use in this study. Extracorporeal and intracorporeal knot tying were excluded on the basis that this is considered an advanced laparoscopic skill in the UK and, within the confines of this study, the time available for initial teaching of this more complex skill to trainees at the beginning of basic laparoscopic training was inadequate.

The transfer task required six Polo mints to be transferred between two poles, sited 7.5 cm apart within the box trainer, and then back, with a transfer between both hands each time (12 transfers). Polo is a registered trademark of Nestle. It is a circular mint with a depth of 4 mm and diameter of 19 mm with the internal hole measuring 8 mm in diameter (Fig. 2). The shape-cutting task required a 4 cm diameter circular pattern to be cut with laparoscopic scissors from 10 × 10 cm thin cleaning cloth material suspended between two alligator clips within the box trainer. A grasper was also used. Further detail of the two tasks and how they were scored is shown in Figs. 3 and 4.

Video assessment and statistical analysis

Assessment of the recorded videos was undertaken by a single assessor who was not aware of the group allocation until after assessment had been undertaken. The tasks were assessed according to the objective measurements originally devised and validated by Derossis et al.[13] The theoretical range for the score for each task was from 0 to 300, with 300 being the highest possible score. After baseline and final assessments had been performed, the change in score for each task could be calculated for each individual participant. The total changes in scores for the control and intervention group were then compared using the Mann-Whitney U test for statistical significance. Only paired data were assessed; therefore, if a participant did not have baseline and final assessment data available, they were excluded from the analysis. Statistical analysis was performed using Microsoft Excel, GraphPad and MedCalc software. In order to confirm reliability of the assessment, 10 videos were also assessed by a second blinded assessor, and the inter-observer variability was checked with a Bland-Altman analysis.

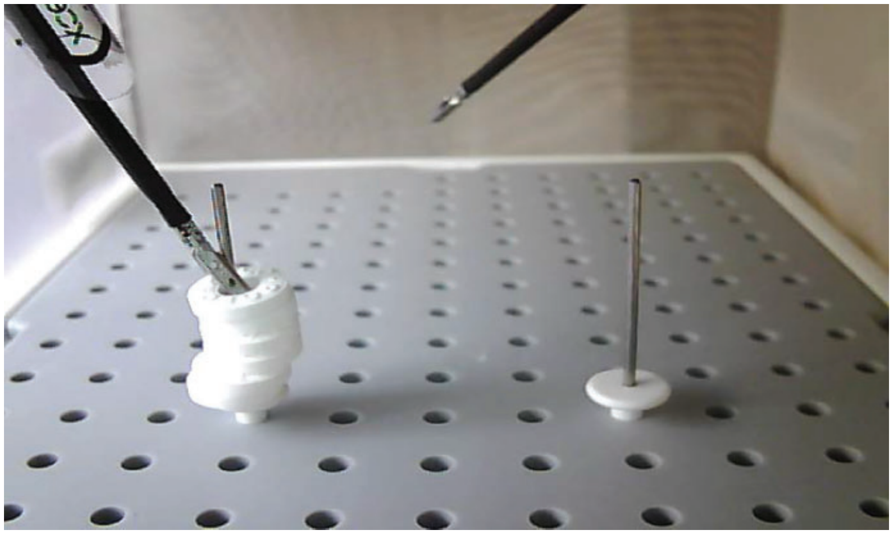
Post-study participant survey

All trainees, from both control and intervention groups, were provided with a laparoscopic box trainer for unsupervised use during their second year of CST. At the end of this second year, they were invited to participate in an online survey. The survey used multiple choice questions and free text responses to assess the frequency with which they used their laparoscopic box trainer, where they used it, ease of use, kit breakages, how helpful to training they found their box trainer, which tasks they felt were suited to practising on the box trainer, what they felt the limitations of the box trainer were and how they felt they could be best used to improve their surgical training.

Results

Thirty trainees were invited to participate. All accepted and were randomized to the control (n = 15) and intervention (n = 15) groups.

Due to technical problems, data were not available for 13/60 (22%) of the baseline assessments. The technical issues were resolved by the time of the final assessments. Data missing from the final assessments was due to 9/30 (30%) participants dropping out of the study. As we were comparing baseline and final assessments for each participant, the combined effect of these technical issues and participant drop-out was to reduce the number of complete pairs of assessments available for analysis. This is illustrated in the CONSORT diagram (Fig. 5) and further exploration of these limitations is undertaken in the discussion.



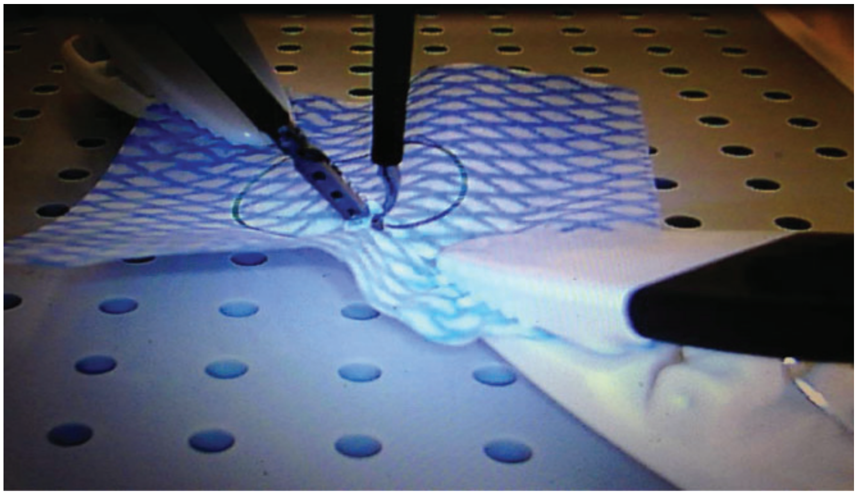
Transfer task
6 polo mints to be transferred between 2 poles, sited 7.5cm apart within the box trainer, and then back, with a transfer between both hands each time (12 transfers). Time limit: 300 secs (5mins)
Timing score = 300 – time to complete task in seconds
Penalty points = Percentage of 12 transfers not completed
Total score = timing score – penalty score
Standardisation: The task must be completed with graspers in both hands, transferring the polo between the two graspers before placing on the opposite pole. The polo mints may be dropped without penalty as long as they are re-grasped with the grasper in the other hand to place on the post. If, however, they are dropped outside the field of view then they will not be able to be transferred. If the polo is not transferred then it is counted as a penalty as calculated above.

Figure 3. The transfer task.

Pre-study survey and training log results

Compliance with the log of operating and simulation experience was extremely poor and no trainee completed this accurately. To the best of our knowledge, other simulators were not routinely available in the Severn region during this period. It is possible that trainees might have been able to use simulators on courses during this time and data on this were not available, but the effect of any such use is likely to have been small. Data on placements were available. Of those who completed the study in the control group seven, all but one did at least 6 months of the year in specialties with general surgery on call (general surgery, vascular surgery, and urology). In this group, 43% of their time was spent in general surgery and 36% in trauma and orthopaedics. Of those who completed the study in the intervention group (11), all but two did at least 6 months of the year in a specialty with general surgery on call. In this group, 50% of their time was spent in general surgery and 36% in trauma and orthopaedics. The difference between these groups was not significant using a chi-squared test ($P = 0.31$).

Overall 26/30 (87%) trainees completed this survey and 17/26 (65%) believed MIS would form an important part of their workload, 3/26 (12%) felt it would not and 6/26 (23%) were unsure. Per protocol analysis of the groups revealed that 5/8 (63%) of the control group who had completed a pre-study survey and had both sets of data available for analysis felt MIS would form an important part of their future workload, 1/8 (13%) felt it would not and 2/8 (25%) were unsure. In the comparable intervention group, 7/10 (70%) felt MIS would form an important part of their workload, 1/10 (10%) felt it would not and 2/10 (20%) were unsure. Therefore, there were no significant differences in



Shape cutting task
4cm diameter circular pattern cut with laparoscopic scissors from 10x10cm thin cleaning cloth material (see Figure 3) suspended between two alligator clips within the box trainer. A grasper was also used. Time limit: 300secs (5mins)
Timing score = 300 – time to complete task in seconds
Penalty points = Percentage deviation from the perfect circle Percentage deviation from a perfect circle was worked out with standard graph paper by the assessor who viewed the video at a later point.
Total score = timing score – penalty score
Standardisation: The circle was finely drawn as a template from standardised machine-produced 4cm diameter plastic circles.

Figure 4. The shape-cutting task.

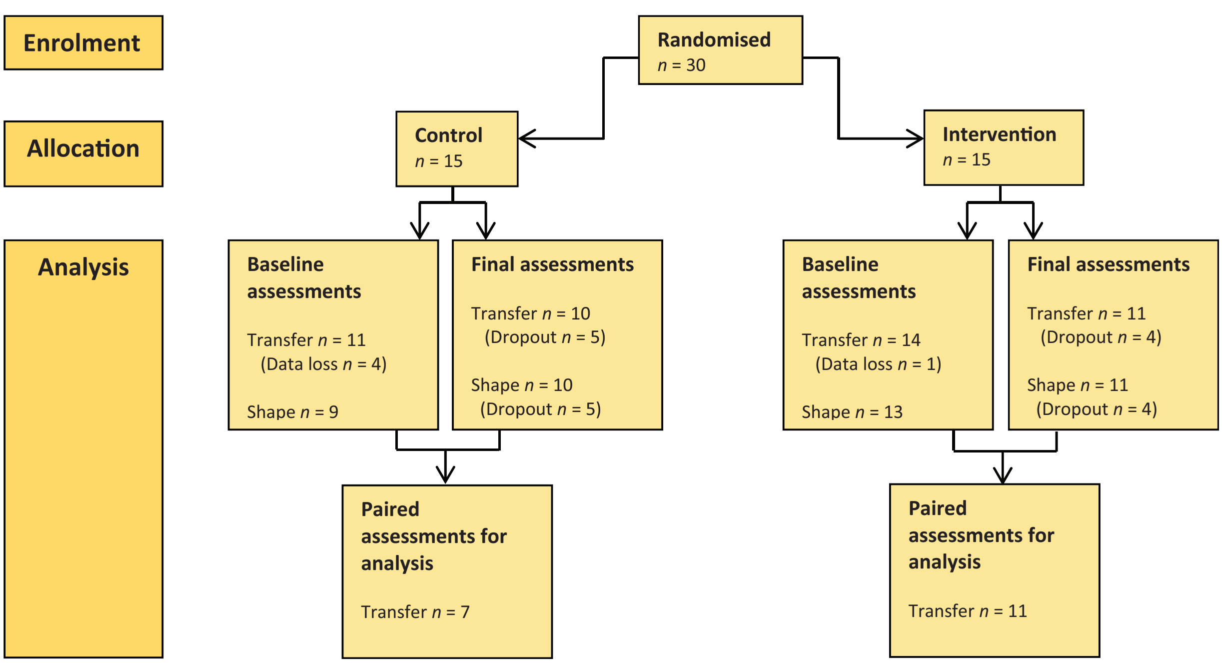


Figure 5. CONSORT flow diagram.

the motivation of the groups in as much as beliefs about future workload might influence this.

Results for the transfer task

For the transfer task, the control group had seven paired assessments available for analysis and the intervention group had 11. The mean improvement in scores were 60.9 for the control group and 106.1 for the intervention group ($P = 0.041$) (Table 1).

Results for the shape-cutting task

For the shape-cutting task, five paired assessments were available for analysis for the control group and 11 for the intervention group. Negative values for the change in score indicated that participant performance was worse after the study period. There was no apparent improvement in scores for either group. The mean change in score was 7.6 for the control group and 4.8 for the intervention group ($P = 0.912$) (Table 2).

Inter-observer correlation

A random sample of 10 videos (five transfer, five shape-cutting) were assessed by another blinded observer, and agreement was calculated using a Bland-Altman plot. The mean difference in score was 11.4 (confidence interval, 5.6–17.2), indicating fair agreement. The Bland-Altman plot can be seen in Fig. 6.

Results of the post-study survey

17/30 trainees responded to the survey invitation (57%). 2/17 (12%) used the trainer once a month or more, 9/17 used the trainer less that once a month (53%) and 6/17 (35%) did not use the trainer at all (Fig. 7). When exploring whether there were technical problems preventing effective use of the kit at home, 9/17 (53%) respondents

Table 1. Results for the transfer task

Participant number (control)	Control transfer score at baseline (A)	Control transfer score at the end of the study period (B)	Control difference (B − A)	Participant number (intervention)	Intervention transfer score at baseline (A)	Intervention transfer score at end of study period (B)	Intervention difference (B − A)
2	93			1	71	189	118
5	63	109	46	3	54	105	51
6		183		4	42	83	41
8				7	28	100	72
9	39			10	12	144	132
11	20	105	85	12	0		
14	89			13	0	180	180
17	99	183	84	15	70	132	62
20	50			16	13		
21	22	44	22	18	77	152	75
23		90		19			
24	82	107	25	22	23		
25	0	100	100	26	30	186	156
27	0	64	64	28	0	122	122
30		153		29	29	187	158
Mean (control)	50.6	113.8	60.9	Mean (intervention)	32.1	143.6	106.1

Table 2. Results for shape-cutting task

Participant number (control)	Control shape-cutting score at baseline (A)	Control shape-cutting score at end of study period (B)	Control difference (B − A)	Participant number (intervention)	Intervention shape-cutting score at baseline (A)	Intervention shape-cutting score at end of study period (B)	Intervention difference (B − A)
2	0			1	0	0	0
5	0	0	0	3	0	0	0
6		48		4	74	0	−74
8				7	0	89	89
9	90			10	20	62	42
11	56	121	65	12	0		
14	78			13	108	0	−108
17	18	0	-18	15	0	0	0
20	0			16	0		
21	80	64	-16	18	0	95	95
23		74		19			
24		16		22			
25		63		26	104	31	−73
27	0	7	7	28	0	0	0
30		0		29	0	82	82
Mean (control)	35.8	39.3	7.6	Mean (intervention)	23.5	32.6	4.8

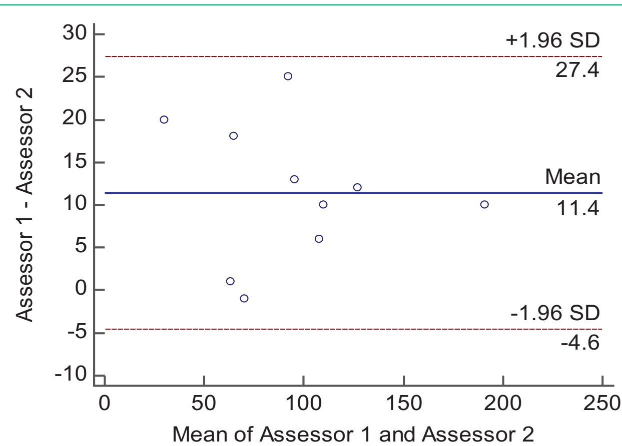


Figure 6. Bland-Altman plot of inter-observer agreement.

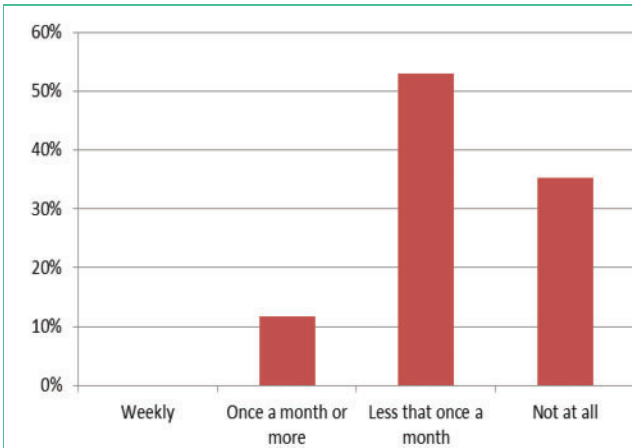


Figure 7. Graph demonstrating frequency of use of the box trainer.

had no problems with setting up the trainer, 5/17 (29%) had some problems that were easily solved and one respondent (6%) could not get the kit set up. Two respondents (12%) did not try and set up their trainer. 2/17 (12%) rated the trainer as very helpful with the majority (9/17, 53%) rating it as sometimes helpful. The remaining 6/17 (35%) either did not use the trainer or rated it not helpful.

15/17 (88%) of responders agreed that the trainer was most useful for general dexterity and transferring. Only one responder (6%) felt it was useful for dissection. 11/17 (65%) felt it would be useful for suturing (Fig. 8). Comments were invited on what the limitations of the box trainers were and these suggested that trainees felt that lack of supervision limited their use, alongside fidelity concerns and the fixed camera position. In addition, respondents were asked for their opinions on how the box trainers could be used to improve CST. Free text comments grouped into themes are given in Tables 3 and 4.

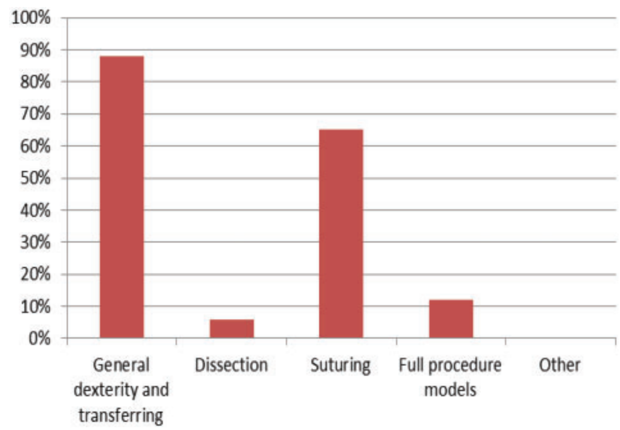


Figure 8. Graph demonstrating respondent opinion on tasks that would be suitable for a box trainer.

Discussion

The development of laparoscopic simulation has been driven by the need to reduce the costs of training in the operating room and to reduce technical errors.[14] Studies have shown that skills learnt on simulators are transferable to the operating environment. and there is a reduction in operative technical errors.[15] The type of simulator used and how best to deliver effective laparoscopic simulation training is, however, still a matter for debate. A proficiency-based VR training curriculum has been shown to shorten the learning curve in laparoscopic procedures when compared with traditional training methods.[3] The cost of VR technology, although remaining higher than that of box trainers, is reducing, and a recent study demonstrated a

Table 3. Free text comments on limitations of the box trainers

Themes	Comments
Camera	The camera had a limited view Mainly realistic positioning of the camera Good for gross skills but quality of webcam made finer skills difficult; e.g. could not easily identify orientation of beads Poor quality camera, flimsy design; however, it was good that it folded up
Fidelity	It would easily move/collapse and for example cutting and suturing were difficult to get adequate tension without the whole system falling apart Only so much one can simulate operating; tissue has a different feel and behaved differently Flimsy so the lid would easily come up, or clips would fall off during use, therefore difficult to create effective tension until you get used to it Small and zoom makes the tasks feel quite confined; he box moves and must be secured to make it more realistic No resistance No real anatomical structures/tissues
Task related	I managed to use it for perfect knot tying Helpful at first, but I used it less as I progressed with laparoscopic skills in theatre and found that performing anything other than the basic skills of transferring objects on the trainer was not that helpful There are only a set few tasks that can be done on it. A box trainer coupled with a simulator/virtual operation would massively increase the scope and benefit the learning curve
Supervision	Useful for preparing for ST3 interviews; but generally need to be taught skills first in order to be able to practice them Lack of supervision so if you get stuck with an activity, it is very difficult to progress When struggling with a skill, it can be difficult to correct as there is no feedback; progression is slower than if appropriately supervised
Technical	My laptop is unfortunately quite old and would not allow meaningful streaming of the video Increase the size; develop a way of securing the box without piling books on each side!
Other	I used it occasionally but as I was primarily doing orthopaedics it did not seem directly relevant to the operations I was learning (we did not do any arthroscopy) Finding the time to use them! Affordability would be an issue if they were bought at a cost to core trainees! Otherwise, consumables are a problem but generally the box trainer was very easy to use Finding the right place at home to keep it set up!

Table 4. Free text comments on how the box trainers could be used to improve core surgical training

Theme	Comments
Integration	May also be helpful to have one in theatres to practice on easily when there is spare time
	Integrated into central teaching sessions
Supervision	Better used in planned teaching sessions with a trainer rather than individual use at home
	Very portable, so easy to set up a session where everyone has one, but realistically, progression of skills requires supervision
	Dedicated sessions with trainers, followed on by using your own box trainer at home to help with practicing newly learnt skills
	If there was a structured programme allowing independent and supervised training so that any difficulties can be easily trouble-shot and progression maintained.
	Tutorial sessions with teachers where they show us and guide us with new skills at the start of CT1 preferably
Assessment	More compulsory/tests on a regular basis

significant reduction in the time taken to perform a simulated laparoscopic cholecystectomy and increased efficiency of movements after use of a take-home VR trainer.[16]

Box trainers are the lower cost alternative, a factor to take into account when considering delivery of training with limited availability of resources. Use of laparoscopic box trainers improved technical skills in trainees with no previous laparoscopic experience.[17] Box trainers and VR correlate positively with each other in terms of time to task completion and the number of errors.[18] Development of tissue handling skills may be superior with the use of box trainers as a result of the maintenance of force feedback by this method,[19,20] and this avoids the prohibitive cost of haptic feedback being incorporated into VR technology. In a study of a low-cost box trainer used to simulate laparoscopic appendicectomy, the face validity was high. A significant difference in performance between junior and middle grade surgeons, but not between middle grade and senior surgeons, suggests that this model has construct validity for basic laparoscopic skills, but a performance plateau is reached.[21]

Our study demonstrates a significantly greater improvement in the intervention group for the transfer task but not the shape-cutting task. The transfer task is predominantly based on hand-eye coordination, whereas the shape-cutting task involves a greater appreciation of force feedback as a vital aspect of dissection. This may be limited by features of the design of the portable box trainer that are difficult to overcome; specifically, the fixed camera view is different from laparoscopic surgery in vivo. The difference between these two types of task is reinforced by the participant survey, which suggests the trainees believe the trainer is useful for general dexterity and transferring rather than dissection. These findings are in line with those of Oliver et al.[21] in terms of demonstrating more significant improvement in basic skills rather than more advanced laparoscopic skills.

This was intended to be a pragmatic study on unsupervised use of box trainers in a real-world context and as such has its limitations. The high drop-out rate is consistent with the literature,[7,8] and further measures need to be taken to improve participation by taking into account the factors that compete for trainee's attention. In addition, there were technical limitations. It was important that the participants were able to use their own laptops with the webcam driver, therefore we opted to use these on the day of the initial assessment in order to ensure the programme was loaded onto them. Although the programme ran adequately on all laptops allowing tasks to be performed, an unforeseen problem arose when trying to save the video of the task for a blinded assessor at a later date. This was related to the size of the video files that were generated by the webcam; some computers did not have the space to store them. There is an argument for standardizing the computers used to record the assessments to reduce data loss, although this would increase the resources required to perform the study. Webcam technology has now advanced so that file sizes are not so large, therefore this should be less of an issue in future. Another possibility to overcome this limitation is the use of independent assessors performing the assessment in real time, however this negates the benefit of being able to record and assess performance remotely and interferes with blinding.

Despite these limitations, the findings of our study are important at a time when resource allocation must be justified. Despite regular calls for take-home resources, the high drop-out rate among study participants and the low rates of use of the trainer indicate that unsupervised practice often does not happen. This is consistent with recent findings where, despite the opinion of self-directed unsupervised skills practice being high when canvassed,[6,22] in practice, the rates of uptake of such opportunities were found to be relatively low.[7,8] This effect seems to be mediated by incorporation into a structured curriculum,[23] although, even then, issues with trainee motivation and time allocated to training were identified. One of the strengths of the present study is the additional information provided by the survey that goes some way towards exploring the reasons for the low uptake of opportunities. Although technical, task-related, and fidelity issues were the predominant themes, it is pertinent that trainees themselves also identified lack of supervision as a limitation. This was reiterated when respondents were asked how the laparoscopic box trainers could be used to improve CST, and the suggestions were all related to themes of integration, supervision and assessment. Further qualitative work could be done to explore this further, but essentially, the responses support the use of these laparoscopic box trainers as part of a curriculum rather than a stand-alone resource.

In conclusion, our study provides evidence that use of portable box trainers without direct supervision is appropriate to aid development of certain basic laparoscopic skills. However, the use of these resources needs to be rigorously supported by a well-planned curriculum, regular senior input and assessment of competency in order to optimize participation of trainees. The difference in improvement between different types of tasks indicates that the unsupervised use of portable box trainers may be optimally deployed at a particular point in the trainee learning curve; specifically, on entry to CST, as a training adjunct for a defined period to improve general dexterity skills. Further study is required to assess whether the scope of take-home trainers can be successfully extended to dissection-based tasks by integration into a curriculum.

Conflict of interest

The authors have declared that no competing financial interests exist. The authors also have no commercial interest or support from any manufacturer or industry to disclose.

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References

1. Toll E, Davis C. More trainees and less operative exposure: a quantitative analysis of training opportunities for junior surgical trainees. Bull R Coll Surg Engl 2010; 92: 170–173. https://doi.org/10.1308/147363510X12689975699630.
2. Burden C, Fox R, Hinshaw K, Draycott TJ, James M. Laparoscopic simulation training in gynaecology: current provision and staff attitudes - a cross-sectional survey. J Obstet Gynaecol 2016; 36: 234–240. https://doi.org/10.3109/01443615.2015.1060199.
3. Aggarwal R, Ward J, Balasundaram I, Sains P, Athanasiou T, Darzi A. Proving the effectiveness of virtual reality simulation for training in laparoscopic surgery. Ann Surg 2007; 246: 771–779. https://doi.org/10.1097/SLA.0b013e3180f61b09.
4. Zendejas B, Cook DA, Bingener J, Huebner M, Dunn WF, Sarr MG, et al. Simulation-based mastery learning improves patient outcomes in laparoscopic inguinal hernia repair: a randomized controlled trial. Ann Surg 2011; 254: 502–509. discussion 509–511. https://doi.org/10.1097/SLA.0b013e31822c6994.
5. Gurusamy KS, Aggarwal R, Palanivelu L, Davidson BR. Virtual reality training for surgical trainees in laparoscopic surgery. Cochrane Database Syst Rev 2009; 1: CD006575. https://doi.org/10.1002/14651858.cd006575.pub2.
6. Partridge R, Hughes M, Brennan P, Hennessey I. There is a worldwide shortfall of simulation platforms for minimally invasive surgery. J Surg Simul 2015; 2: 12–17. https://doi.org/10.1102/2051-7726.2015.0003.
7. Aslam A, Nason GJ, Giri SK. Homemade laparoscopic surgical simulator: a cost-effective solution to the challenge of acquiring laparoscopic skills? Ir J Med Sci 2016; 185: 791–796. https://doi.org/10.1007/s11845-015-1357-7.
8. Zapf MA, Ujiki MB. Surgical resident evaluations of portable laparoscopic box trainers incorporated into a simulation-based minimally invasive surgery curriculum. Surg Innov 2015; 22: 83–87. https://doi.org/10.1177/1553350614535858.
9. Mackay S, Morgan P, Datta V, Chang A, Darzi A. Practice distribution in procedural skills training: a randomized controlled trial. Surg Endosc 2002; 16: 957–961. https://doi.org/10.1007/s00464-001-9132-4.
10. Moulton CA, Dubrowski A, Macrae H, Graham B, Grober E, Reznick R. Teaching surgical skills: what kind of practice makes perfect?: a randomized, controlled trial. Ann Surg 2006; 244: 400–409. https://doi.org/10.1097/01.sla.0000234808.85789.6a.
11. Botden SM, Jakimowicz JJ. What is going on in augmented reality simulation in laparoscopic surgery? Surg Endosc 2009; 23: 1693–1700. https://doi.org/10.1007/s00464-008-0144-1.
12. Gonzalez R, Bowers SP, Smith CD, Ramshaw BJ. Does setting specific goals and providing feedback during training result in

better acquisition of laparoscopic skills? Am Surg 2004; 70: 35–39. PMID:14964544.

13. Derossis AM, Fried GM, Abrahamowicz M, Sigman HH, Barkun JS, Meakins JL. Development of a model for training and evaluation of laparoscopic skills. Am J Surg 1998; 175: 482–487. https://doi.org/10.1016/S0002-9610(98)00080-4.
14. Villegas L, Schneider BE, Callery MP, Jones DB. Laparoscopic skills training. Surg Endosc 2003; 17: 1879–1888. https://doi.org/10.1007/s00464-003-8172-3.
15. Sturm LP, Windsor JA, Cosman PH, Cregan P, Hewett PJ, Maddern GJ. A systematic review of skills transfer after surgical simulation training. Ann Surg 2008; 248: 166–179. https://doi.org/10.1097/SLA.0b013e318176bf24.
16. Barnes J, Burns J, Nesbitt C, Hawkins H, Horgan A. Home virtual reality simulation training: the effect on trainee ability and confidence with laparoscopic surgery. J Surg Simul 2015; 2: 53–59. https://doi.org/10.1102/2051-7726.2015.0012.
17. Nagendran M, Toon CD, Davidson BR, Gurusamy KS. Laparoscopic surgical box model training for surgical trainees with no prior laparoscopic experience. Cochrane Database Syst Rev 2014; 1: CD010479. https://doi.org/10.1002/14651858.cd010479.pub2.
18. Newmark J, Dandolu V, Milner R, Grewal H, Harbison S, Hernandez E. Correlating virtual reality and box trainer tasks in the assessment of laparoscopic surgical skills. Am J Obstet Gynecol 2007; 197: 546.e1–4. https://doi.org/10.1016/j.ajog.2007.07.026.
19. Chmarra MK, Dankelman J, van den Dobbelsteen JJ, Jansen FW. Force feedback and basic laparoscopic skills. Surg Endosc 2008; 22: 2140–2148. https://doi.org/10.1007/s00464-008-9937-5.
20. Botden SM, Torab F, Buzink SN, Jakimowicz JJ. The importance of haptic feedback in laparoscopic suturing training and the additive value of virtual reality simulation. Surg Endosc 2008; 22: 1214–1222. https://doi.org/10.1007/s00464-007-9589-x.
21. Oliver J, Carty N, Wakefield C. Low-cost model for laparoscopic appendicectomy in a webcam simulator. Bull R Coll Surg Engl 2010; 92: 122–125. https://doi.org/10.1308/147363510X489667.
22. van der Aa JE, Schreuder HW. Training laparoscopic skills at home: residents' opinion of a new portable tablet box trainer. Surg Innov 2016; 23: 196–200. https://doi.org/10.1177/1553350615610654.
23. Bjerrum F, Sorensen JL, Thinggaard J, Strandbygaard J, Konge L. Implementation of a cross-specialty training program in basic laparoscopy. JSLS 2015; 19: e2015.00059. https://doi.org/10.4293/JSLS.2015.00059.