DOI: 10.1111/j.1471-0528.2011.03146.x
www.bjog.org

Laparoscopic skills training using inexpensive box trainers: which exercises to choose when constructing a validated training course

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Accepted 2 August 2011. Published Online 7 October 2011.

Objective To obtain face and construct validity for a new training course to be used in any type of box/video trainer and to give a comprehensive overview of validated exercises for box/video training.

Design Cross-sectional study.

Setting University Medical Centre.

Population Students, residents and consultants.

Methods Participants (n = 42) were divided into three groups according to their laparoscopic experience: 'Novices' (n = 18), 'Intermediates' (n = 14) and 'Experts' (n = 10). A laparoscopic training course consisting of six exercises was constructed. To emphasise precision, a penalty score was added. Every participant performed two repetitions of the exercises; total score per exercise was calculated. To determine face validity, participants filled in a questionnaire after completion of the exercises. An evidence-based literature search for validated box/video trainer exercises was performed.

Main outcome measures Face and construct validity.

Results The mean score of the 'experts' was set as the training target. Total scores appeared to be positively correlated with individual's laparoscopic experience. The overall score and the score for each exercise were significantly higher in the intermediate and expert groups when compared with the novice group ($P \leq 0.001$). All participants completed the questionnaire. The overall assessment of the exercises was considered to be good. The course was found to be most appropriate for training residents year 1–3.

Conclusion Face and construct validity for an inexpensive course for box/video training was established. A comprehensive and practical overview of all validated and published exercises for box/video trainers is provided to facilitate an inexpensive, but optimal and tailored selection for training purposes.

Keywords Box training, education, laparoscopy, simulation, validated exercises, video training.

Please cite this paper as: Schreuder H, van den Berg C, Hazebroek E, Verheijen R, Schijven M. Laparoscopic skills training using inexpensive box trainers: which exercises to choose when constructing a validated training course. BJOG 2011;118:1576–1584.

Introduction

To perform laparoscopic surgery safely, several unique psychomotor skills are required from the surgeon. These include adaptation to the conversion from three-dimensional to two-dimensional vision, bi-manual dexterity, handling long instruments with an amplified tremor, dealing with the fulcrum effect and reduced tactile feedback. Simulation can be used to master these skills. Training on simulation models leads to a faster pace of the learning curve of the individual surgeon in a safe environment, thereby decreasing the burden on operating time and costs and increasing patient safety.[1,2] Different simulation models and scenarios have been introduced and incorporated into various laparoscopic training curricula.[3] In general, these models can be categorised as *in vivo* anaesthetised or *ex vivo* animal trainers, high-fidelity and low-fidelity virtual reality simulators and inanimate box or video trainers.[1,4–8] The training capacities of box trainers and virtual reality trainers are comparable and no difference was found in laparoscopic skills acquisition when incorporating virtual reality trainers in a training curriculum based on box trainers.[9] There is a good correlation between both trainers for the assessment of laparoscopic skills, although box trainers do require a supervisor for assessment whereas outcome assessment is embedded in most virtual reality trainers.[10]

Compared with virtual reality trainers, box trainers have the advantage of being inexpensive and easy realisable, so they have better availability throughout hospitals. Next, standard endoscopic instruments may be used and haptic feedback is preserved as in the operative environment. This contributes to the reality of training and a proper transfer of skills to the operating room. Because of their low cost, box trainers are a feasible choice in providing training opportunities at home.[11] In a cost-effective laparoscopic skills curriculum, box trainers may be used alone or in combination with virtual reality trainers and animate models. A major advantage of box trainers is the preservation of haptic feedback and the opportunity to use standard endoscopic instruments. This kind of feedback is important to simulate laparoscopic surgery in a realistic way. Chmarra et al.[12] found a positive influence of box training on laparoscopic exercises, when tactile forces do play an important role (e.g. stretching, grasping). Even though box training lacks integrated objective assessment compared with virtual reality simulation, this feature is considered to be an important one. Box training may therefore be considered indispensable in a truly comprehensive laparoscopic training curriculum.

Before implementing and using any simulation model in a laparoscopy curriculum, it is important to determine the validity of the simulation model. Important steps in this process are the aspects of face validity and construct validity of the box trainer for training purposes. Face validity specifically addresses the question of to what extent the instrument does simulate what it is supposed to represent, and so refers to the degree of resemblance between the box trainer and the actual construct (development of psychomotor laparoscopic surgical skill), as judged by a specific target population. Construct validity refers to the degree of empirical foundation of the box trainer. Hence, a logical difference in outcome between two research populations (e.g. experienced surgeons outperform inexperienced surgeons on the box trainer curriculum) is to be expected.[13] Unfortunately, scientific validation of these relatively inexpensive and commercially available exercises for box trainers is relatively scarce.

The aim of this study was to establish face and construct validity of six newly developed exercises for a box/video trainer to be used in a laparoscopic skills programme. In addition to the validation study, we provide a clear and practical overview of the currently available validated exercises for box trainers.

Methods

A newly developed set of laparoscopic exercise boards to be used in a box/video trainer was used for this study (3-Dmed®, Franklin, OH, USA). From April to June 2010, a validation study was performed at the Department of Gynaecology of the University Medical Centre in Utrecht, the Netherlands. All exercises were performed in a 42 × 32 × 24 cm box trainer with a fixed position camera (Covidien® Surgical Box, Mansfield, MA, USA). Two reusable laparoscopic graspers (Karl Storz®, Tuttlingen, Germany) were used to perform the exercises. A simple digital timer was used to measure the time.

Participants

Medical students (fifth and sixth year medical school), residents and consultants from the Department of Gynaecology, Surgery and Urology participated in the study ($n = 42$). According to their respective laparoscopic experience, three study groups were formed. Group 1 'novice' ($n = 18$) consisted of medical students with no laparoscopic experience. Group 2 'intermediate' ($n = 14$) consisted of residents with moderate laparoscopic experience. 'Moderate laparoscopic experience' was defined as having performed none or fewer than ten advanced laparoscopic procedures. In this group, residents in their first to sixth year of training in gynaecology, surgery or urology participated. Group 3 'experts' ($n = 10$) consisted of experienced laparoscopic surgeons, who had all performed >50 advanced procedures. Advanced procedures for gynaecologists were: laparoscopic hysterectomy, laparoscopic sacrocolpopexy and laparoscopic lymphadenectomy; for general surgeons they were: laparoscopic Nissen fundoplication, laparoscopic colectomy and laparoscopic bariatric procedures; and for urologists the laparoscopic prostatectomy was selected as an advanced procedure. None of the participants had previous experience with this specific laparoscopic training set.

Exercises

Four different boards, each with a different configuration, were available to perform box trainer exercises. We defined six exercises: 'Post and sleeve', 'Loops and wire', 'Pea on a peg', 'Wire chaser (one hand)', 'Wire chaser (two hands)' and 'Zigzag loops' (Figure 1). A proper description of the exercises was constructed and exercise-specific penalty scores were defined. Outcome parameters were set, and the 'total score', based on time and precision, was calculated by adding the exercise completion time to the penalty score. A lower score correlated with a better performance. The goal of the different exercises is to train and test various skills, such as hand–eye coordination, manual dexterity, depth perception and interaction of the dominant and non-dominant hand. The different exercises are described in detail below.

Exercise 1

'Post and sleeve' (Video S1). The six sleeves are positioned on the left side of the board. The sleeves have to be picked up with the left hand, passed over to the right hand and then transferred to their mirrored posts on the opposite side. After the six sleeves have been moved successfully to

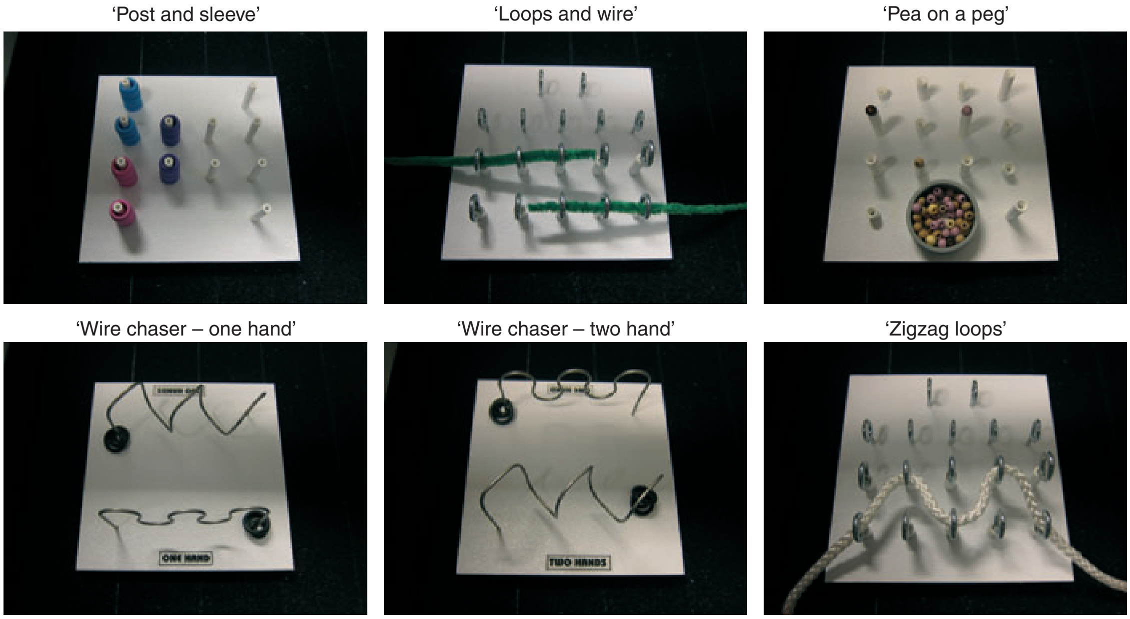

Figure 1. Exercises.

the other side, the exercise is to be repeated in the opposite direction, now starting with the right hand. Per dropped sleeve ten penalty points are counted.

Exercise 2
'Loops and wire' (Video S2).The board is positioned with four loops in front, two pipe cleaners are lying in front. The first pipe cleaner has to be introduced from the right side through the loops; the next pipe cleaner has to be introduced from the left side. Next, the two pipe cleaners must be passed through the first two rows of four loops, alternating dominant hand manoeuvres whenever appropriate. The task is finished when both pipe cleaners are successfully placed through the two rows of loops. If a pipe cleaner is passed alongside a loop during the procedure, ten penalty points are counted.

Exercise 3
'Pea on a peg' (Video S3). The board is positioned with the cup, containing at least 25 wooden beads, in front. Fourteen wooden beads must be taken out one-by-one from the cup and placed on various pegs of different heights. The left side of the pegboard has to be completed with the left hand, the right side with the right hand. When a bead is dropped next to the pegboard, it cannot be used. When a bead falls on the pegboard it has to be picked up again to be successfully placed on a peg. Ten penalty points are counted when a bead is dropped on the pegboard; twenty penalty points are counted when a bead falls off the pegboard.

Exercise 4
'Wire chaser (one hand)' (Video S4). The board is positioned with the text 'one hand' in front. Three rings, with decreasing diameter, must be transferred one-by-one to the other side of the wire, using the dominant hand. If the ring is lost by the instrument, ten penalty points are counted.

Exercise 5
'Wire chaser (two hands)' (Video S5). The board is positioned with the text 'two hands' in front. Three rings, with decreasing diameter, must be transferred one-by-one to the other side of the wire, starting with the dominant hand. Both hands are used and hands need to change after each curve in the ring. If the ring is lost by the instrument, ten penalty points are counted.

Exercise 6
'Zigzag loops' (Video S6). The board is positioned with four loops in front, the rope is lying in front. The rope must be passed through the four loops of the first and second row of the loop-board, resulting in a zigzag pattern. This has to be performed using both hands, starting from the right side. If the rope is passed beside a loop during the procedure, then ten penalty points are counted.

Face validity

All participants were asked to fill out a questionnaire, immediately after performing the six exercises to obtain information about their general characteristics, educational background and their general impression of the exercises. Questions 1–8 related to demographics and laparoscopic experience. Questions 9–24 included questions about the exercises' appearance, materials, feasibility, difficulty, training capacity and opportunities for implementation. The questions were presented on a five-point Likert scale.

Construct validity

To establish construct validity, all participants performed the six different exercises twice. Before each exercise the participants read the short instructions. Next, each exercise was briefly explained verbally and subsequently demonstrated by the test supervisor. The first run was used as a familiarisation run, whereas the second run was in fact used to determine construct validity. The individual times and scores of the three groups were compared to evaluate the discriminative capacity of the task set for trainees with different laparoscopic experience. Based on the extracted data the target levels for each exercise and the six exercises together were defined by calculating the mean scores of the expert group.

Statistics

SPSS 15.0 statistical software (SPSS Inc, Chicago, IL, USA) was used to analyse the data. One-way analysis of variance with multiple comparisons (*post hoc* Bonferroni test) was used to obtain differences between the three groups. P-values ≤ 0.05 were considered to be statistically significant; alpha was chosen at the 0.05 level.

Results

The participants ($n = 42$) were categorised into three groups based on their laparoscopic experience: novices ($n = 18$), intermediates ($n = 14$), experts ($n = 10$). Demographic data and previous training experience are shown in Table 1. Intermediates had more training experience on box trainers and virtual reality trainers than experts.

Table 1. Characteristics participants

	Novices (n = 18)	Intermediates (n = 14)	Experts (n = 10)
Mean age (range)	24 (23–26)	29 (25–34)	43 (36–54)
Gender			
Male	6	8	9
Female	12	6	1
Hand dominance			
Left-hand dominant	2	2	0
Medical specialty			
Gynaecology	N/A	8	6
Surgery	N/A	3	3
Urology	N/A	3	1
Experience with laparoscopic box training (no. of times)			
None	14	3	2
1–5	4	3	2
6–10	0	3	1
11–20	0	3	0
>20	0	2	5
Experience with laparoscopic box training (hours)			
N/A	14	3	2
1–5	4	0	3
6–10	0	3	1
11–20	0	7	2
21–50	0	1	2
>50	0	0	0
Experience with laparoscopic virtual reality training (no. of times)			
None	14	3	3
1–5	4	8	3
6–10	0	2	1
11–20	0	0	1
>20	0	1	2
Experience with laparoscopic virtual reality training (hours)			
None	15	3	3
1–5	2	6	3
6–10	0	2	2
11–20	1	3	0
21–50	0	0	2
>50	0	0	0
Laparoscopic experience	N/A	None or <10 advanced procedures	>50 advanced procedures

N/A, not applicable.
Data are presented as mean (range) or number.

Face validity

All participants completed the questionnaire ($n = 42$). The overall assessment of the exercises for developing laparoscopic psychomotor skill was considered to be uniformly 'good', all being rated above 4.0 on the five-point Likert scale (Table 2). The novices, intermediates and experts rated the complete programme of six exercises 4.1, 4.3 and 4.1 points, respectively. Difficulty of exercises was rated to be between 'intermediate' and 'difficult'. The participants were also asked for their opinion about the suitability of these exercises to different levels of laparoscopic experience. They expected the exercises to be most appropriate for postgraduate residents years 1–3 and least appropriate for laparoscopic experts. After the general assessment, participants had to evaluate each exercise separately. The assessment of different aspects of the exercises separately is shown in Table 3.

Construct validity

All participants ($n = 42$) completed the two repetitions of the six exercises. The total score (time + penalties) for each exercise and the overall score are shown in Table 4. The mean overall score and the mean score for each exercise separately were significantly higher in both the intermediate

Table 2. Face validity (general assessment)*

	Novices (n = 18)	Intermediates (n = 14)	Experts (n = 10)	Mean
Suitability to train psychomotor skills	4.2 ± 0.6	4.1 ± 1.3	4.4 ± 0.5	4.2 ± 0.9
Possibility to assess the exercises on the basis of objective parameters	3.9 ± 0.5	3.7 ± 1.0	3.6 ± 0.7	3.7 ± 0.7
Difficulty of exercises	3.2 ± 0.6	3.3 ± 0.8	3.4 ± 0.5	3.3 ± 0.7
These exercises are appropriate for box training	4.3 ± 0.7	4.2 ± 0.9	4.6 ± 0.7	4.3 ± 0.7
Training capacity				
Eye/hand coordination	4.1 ± 0.7	4.3 ± 0.9	4.3 ± 0.7	4.2 ± 0.7
Depth perception	3.3 ± 0.8	3.7 ± 1.4	3.4 ± 1.2	3.5 ± 1.1
Training both hands separately	4.0 ± 0.6	4.2 ± 0.4	4.3 ± 0.5	4.1 ± 0.5
Training both hands together	3.8 ± 0.8	4.2 ± 0.4	4.0 ± 0.0	4.0 ± 0.6
Fitness for different levels of experience				
Residents PGY 1–3	4.3 ± 0.5	4.9 ± 0.3	4.4 ± 0.7	4.5 ± 0.5
Residents PGY 4–6	3.1 ± 1.1	3.8 ± 1.0	4.4 ± 0.7	3.6 ± 1.1
Medical specialist	2.6 ± 1.1	3.1 ± 0.7	3.7 ± 1.1	3.0 ± 1.0
Laparoscopic expert	2.0 ± 1.0	2.1 ± 0.8	2.6 ± 1.1	2.2 ± 0.8
Box training should be part of a laparoscopic curriculum	4.1 ± 0.6	4.6 ± 0.6	4.5 ± 0.7	4.4 ± 0.7
VR training should be part of a laparoscopic curriculum	3.9 ± 0.8	4.6 ± 0.5	4.6 ± 0.7	4.3 ± 0.8
Box training and VR training should both be part of a laparoscopic curriculum	4.2 ± 0.7	4.9 ± 0.3	4.8 ± 0.4	4.6 ± 0.6
Overall assessment	4.1 ± 0.4	4.3 ± 0.6	4.1 ± 0.6	4.1 ± 0.5

PGY, postgraduate year; VR, virtual reality.
Data are presented as mean ± SD.
*Ratings on a 1 to 5 Likert scale (1 = very bad/strongly disagree, 2 = bad/disagree, 3 = neutral, 4 = good/agree, 5 = very good/strongly agree).

group ($P < 0.001$) and the expert group ($P < 0.001$), compared with the novice group. The mean overall scores of the novice, intermediate and expert groups were 1891, 1022 and 763, respectively. There was a significant difference comparing the novice group with the intermediate group ($P < 0.001$) or expert group ($P < 0.001$). No statistical significance was reached between the intermediate and the expert groups ($P = 0.369$) (Figure 2). However, the set-up is likely to be construct valid in the sense that more laparoscopic experience appeared to be associated with a better performance.

Discussion

In this study, face and construct validity was obtained for six newly available exercises for laparoscopic skills training. Combined, they constitute a short training curriculum ready to use in any box or video trainer. A significant difference between non-experienced and experienced laparoscopic participants was found. However, the difference between the intermediate group and expert group was not statistically significant. An explanation could be the fact that the participants in the intermediate group were already used to training on both box and virtual reality trainers. This bias is unavoidable because box training is an essential part of laparoscopic training and most residents have therefore spent more time training on simulators then experts. Two of the six exercises in the current study show some similarity to exercises described in other laparoscopic programmes; exercise 1 ('Post and sleeve')[14–18] and exercise 2 ('Loops and wire').[19] Innovative exercises are exercise 3 ('Pea on a peg'), exercise 4 ('Wire chaser [one hand]') and exercise 5 ('Wire chaser [two hands]'). A majority of the participants found exercise 3 ('Pea on a peg') to be the most difficult exercise, but assessed this exercise very positively. Probably this is because this exercise trains important skills, like subtle movement and coordination.

In laparoscopic surgery the trainee/surgeon needs to acquire new and different skills compared with open surgery. In this training course, the conversion from three-dimensional to two-dimensional vision and dealing with the fulcrum effect is being trained in all exercises. Bi-manual dexterity is specifically trained in exercises 2, 3, 4, 5 and 6. Handling long instruments with amplified tremor is specifically trained in exercise 3, which needs precision and stability of the instruments. Reduced tactile feedback plays a role in exercise 3. Task time is an important parameter in simulation training, but task time alone has its limitations. One may cause serious adverse events when performing too fast in laparoscopy. To overcome this problem and to force the trainee to work carefully a penalty score for certain mistakes was introduced. The penalty score will keep the

Table 3. Face validity (assessment by exercise)*

	Novices (*n* = 18)	Intermediates (*n* = 14)	Experts (*n* = 10)	Mean
Exercise 1: 'Post and sleeve'	4.0 ± 0.5	4.4 ± 0.4	4.2 ± 0.6	4.2 ± 0.5
Appearance	4.1 ± 0.6	4.4 ± 0.5	4.3 ± 0.9	4.2 ± 0.7
Practicability	4.1 ± 0.5	4.6 ± 0.5	4.7 ± 0.5	4.4 ± 0.5
Material	4.1 ± 0.9	4.6 ± 0.5	4.4 ± 0.7	4.3 ± 0.8
Projection in the box	4.1 ± 0.8	4.4 ± 0.7	3.8 ± 0.4	4.1 ± 0.7
Training capacity	3.9 ± 0.7	4.2 ± 0.7	4.0 ± 0.9	4.0 ± 0.7
Exercise 2: 'Loops and wire'	3.9 ± 0.5	3.8 ± 0.8	4.1 ± 0.6	3.9 ± 0.6
Appearance	3.9 ± 0.6	3.9 ± 1.0	3.9 ± 0.6	3.9 ± 0.7
Practicability	4.1 ± 0.6	4.1 ± 0.8	4.7 ± 0.7	4.3 ± 0.6
Material	3.9 ± 1.0	3.8 ± 1.1	4.4 ± 0.8	4.0 ± 0.9
Projection in the box	4.0 ± 0.8	4.0 ± 0.9	3.9 ± 1.0	4.0 ± 0.8
Training capacity	3.8 ± 0.6	3.9 ± 0.7	3.7 ± 0.8	3.8 ± 0.7
Exercise 3: 'Pea on a peg'	4.0 ± 0.6	4.3 ± 0.6	4.3 ± 0.6	4.2 ± 0.6
Appearance	4.1 ± 0.8	4.5 ± 0.7	4.5 ± 0.7	4.3 ± 0.7
Practicability	3.7 ± 0.8	4.0 ± 1.0	4.3 ± 0.7	4.0 ± 0.9
Material	4.1 ± 0.9	4.1 ± 1.2	4.2 ± 0.8	4.1 ± 0.9
Projection in the box	3.9 ± 0.8	4.0 ± 0.7	3.5 ± 0.7	3.8 ± 0.8
Training capacity	4.3 ± 0.8	4.6 ± 0.5	4.3 ± 0.8	4.4 ± 0.7
Exercise 4: 'Wire chaser' (one hand)	3.5 ± 0.7	3.4 ± 1.2	3.6 ± 0.7	3.5 ± 0.9
Appearance	3.8 ± 0.6	3.9 ± 1.3	3.8 ± 0.6	3.8 ± 0.9
Practicability	3.3 ± 0.8	3.2 ± 1.4	4.0 ± 1.1	3.5 ± 1.1
Material	3.6 ± 1.1	3.2 ± 1.4	3.6 ± 1.2	3.5 ± 1.1
Projection in the box	3.4 ± 1.2	3.6 ± 1.2	3.4 ± 1.1	3.5 ± 1.2
Training capacity	3.5 ± 0.9	3.3 ± 1.3	3.4 ± 1.0	3.4 ± 1.0
Exercise 5: 'Wire chaser' (two hands)	3.7 ± 0.6	3.6 ± 1.1	3.4 ± 0.6	3.6 ± 0.8
Appearance	3.8 ± 0.6	3.7 ± 1.3	3.9 ± 0.6	3.8 ± 0.9
Practicability	3.5 ± 0.8	3.4 ± 1.2	3.6 ± 1.0	3.5 ± 0.9
Material	3.8 ± 0.7	3.4 ± 1.2	3.7 ± 1.1	3.6 ± 1.0
Projection in the box	3.5 ± 0.9	3.8 ± 1.1	3.0 ± 1.2	3.5 ± 1.1
Training capacity	3.9 ± 0.8	3.6 ± 1.1	3.3 ± 0.8	3.7 ± 0.9
Exercise 6: 'Zigzag loops'	4.1 ± 0.7	4.0 ± 0.7	4.1 ± 0.9	4.1 ± 0.7
Appearance	4.1 ± 0.8	3.9 ± 0.9	4.3 ± 0.8	4.0 ± 0.8
Practicability	4.3 ± 0.9	4.1 ± 0.7	4.4 ± 0.8	4.3 ± 0.8
Material	4.0 ± 0.9	4.1 ± 0.8	4.4 ± 1.1	4.1 ± 0.9
Projection in the box	4.3 ± 0.7	3.9 ± 0.8	3.8 ± 0.9	4.0 ± 0.8
Training capacity	3.9 ± 0.9	3.9 ± 0.8	3.8 ± 0.9	3.9 ± 0.8

Data are presented as mean ± SD.
*Ratings on a 1 to 5 Likert scale (1 = very bad, 2 = bad, 3 = neither good nor bad, 4 = good, 5 = very good).

trainee more focused compared with using task time alone, and prevents trainees 'chasing' for efficiency whereas compromising precision. This kind of scoring system was previously used in other box training validation studies.[17,19]

Laparoscopic simulators have become an indispensable part of every laparoscopic skills programme. To be optimally effective, simulator training should be incorporated in an obligatory and competence-based laparoscopic skills curriculum. This implies that training is based on the progress of the trainee instead of being based on the mere time spent on training. For programme directors it is now possible, by choosing different exercises, to develop and tailor their own laparoscopic skills curriculum to their resources, goals and needs. In these way affordable skills curricula can be created. Special attention has to be paid in choosing exercises to be used in a self-constructed unmonitored laparoscopic skills curriculum. These exercises should be clearly described and validated. Before embarking on independent training, a demonstration must be provided to avoid misinterpretations and a test round must be observed to check the system and inappropriate handling of instruments. There must also be a clear and predefined goal or level that is to be reached by the trainee.[20]

Several exercises for use in box trainers have been developed. The McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS) has been widely studied.[1,14–16,21,22] Based on certain MISTELS tasks the Society of American Gastrointestinal Endoscopic Surgeons developed the Fundamentals of Laparoscopic Surgery (FLS) programme.[23] The FLS programme includes a box-trainer-based technical skill component, a didactic component and an assessment component.[24] Next to this complete programme, which is used worldwide, we think there is a need for easy usable exercises for box training. Such exercises could be used in box trainers in the operating room department or in the resident room and could be incorporated in training curricula. However, many of the available exercises are not validated for their intended purpose. We provide, next to the exercises validated in this study, an overview of the currently available and validated exercises for box or video trainers (Figure S1 and Table S1).[1,6,19,25–40] This overview may be helpful for trainers and programme directors in the selection of the appropriate training exercises in constructing a training curriculum. Most of the exercises can be constructed by the instructor[6,25,26] or are readily commercially available.[17,22,23,27–30]

Besides box trainers, virtual reality trainers may used in a laparoscopic skills curriculum. Virtual reality trainers have the advantage of objective assessment and high-fidelity simulators are able to offer training of full procedural tasks. As for haptic feedback, authors believe that they are potentially inferior to a box trainer. A disadvantage of virtual reality is the high cost when compared with box trainers,

Table 4. Construct validity (total score = time + penalties)

Exercises	Group 1	Group 2	Group 3	ANOVA	Multiple comparisons	*Post hoc* Bonferroni
	Novices (n = 18)	Intermediates (n = 14)	Experts (n = 10)			
	Mean score (range)	Mean score (range)	Mean score (range)	*P*-value (≤0.05)		*P*-value (≤0.05)
Post and sleeve	299 (159–602)	161 (91–307)	120 (78–232)	<0.001	1 > 2	<0.001
					1 > 3	<0.001
					2 > 3	0.759
Loops and wire	176 (111–298)	108 (59–176)	86 (61–121)	<0.001	1 > 2	<0.001
					1 > 3	<0.001
					2 > 3	0.690
Pea on a peg	771 (345–1450)	404 (186–768)	313 (203–552)	<0.001	1 > 2	<0.001
					1 > 3	<0.001
					2 > 3	1.000
Wire chaser (one hand)	195 (60–417)	113 (31–306)	69 (23–182)	<0.001	1 > 2	0.019
					1 > 3	<0.001
					2 > 3	0.573
Wire chaser (two hands)	317 (191–503)	166 (78–371)	127 (74–248)	<0.001	1 > 2	<0.001
					1 > 3	<0.001
					2 > 3	0.685
Zigzag loops	134 (69–219)	70 (29–136)	48 (28–82)	<0.001	1 > 2	<0.001
					1 > 3	<0.001
					2 > 3	0.397
Overall score	1891 (1102–2683)	1022 (621–2030)	763 (523–1199)	<0.001	1 > 2	<0.001
					1 > 3	<0.001
					2 > 3	0.369

One-way analysis of variance (ANOVA) was used to define the difference between the three groups. Multiple comparisons with the *post hoc* Bonferroni test were used to define the difference between the three groups separately. Exact *P*-values were calculated and are shown to three decimal places.

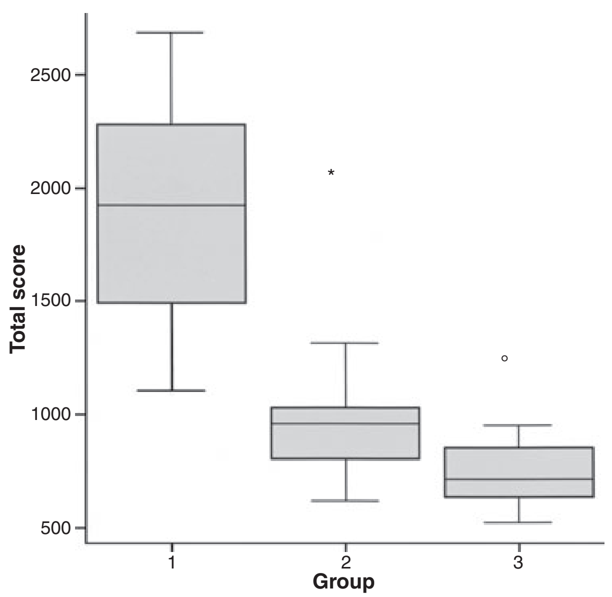

Figure 2. The total score of the six exercises of group 1 (novices), group 2 (intermediates) and group 3 (experts). The differences between groups 1 and 2 and groups 1 and 3 were significant ($P < 0.001$). * and ° are outliers.

which can be a burden for many hospitals. In these situations, a well-designed, competence-based validated laparoscopic skills curriculum using box trainers only, can be sufficient. Palter et al.[41] investigated resident perceptions regarding different forms of laparoscopic simulation. Their study showed residents even preferred box training above virtual reality training for training advanced laparoscopic skills. This should be taken into account when designing a surgical skills curriculum for advanced laparoscopy.

Today, laparoscopic simulators play an important role in learning and training minimal invasive surgery. To maximise training capacities the simulators should be implemented in an obligatory competence-based or proficiency-based laparoscopic skills curriculum. In such a curriculum, box/video trainers and virtual reality trainers may be used alone or in combination. Only validated exercises with a proper training goal should be used in a skills curriculum. In terms of cost-effectiveness, the box trainer remains unsurpassed.

Disclosure of interests

For all authors there is no financial interest.

Contribution to authorship

All authors meet the criteria to qualify for authorship, in detail: HS designed the study, wrote the manuscript and analysed the data. CB wrote the manuscript and collected and analysed the data. EH helped with the study design and revised the manuscript. RV helped with the study design and revised the manuscript. MS designed the study, assisted in analyses and revised the manuscript.

Details of ethics approval

Not applicable.

Funding

No funding was received.

Acknowledgements

We would like to thank all participants.

Supporting information

The following supplementary materials are available for this article:

Figure S1. Flowchart literature search.
Video S1. Post and sleeve.
Video S2. Loops and wire.
Video S3. Pea on a peg.
Video S4. Wire chaser (one hand).
Video S5. Wire chaser (two hands).
Video S6. Zigzag loops.
Table S1. Overview of validated box trainer exercises.

Additional Supporting Information may be found in the online version of this article.

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