Validation and efficacy of the Varix Trainer model as a Training device for esophagogastroduodenoscopy

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ABSTRACT

Background and study aims The Varix Trainer model 1 (VTM1) was created for trainees to safely practice basic endoscope manipulation skills. The VTM1 was tested to see if it could distinguish levels of endoscope manipulation skills (construct validity) and whether training with it could improve these skills faster (content validity).

Patients and methods We enrolled 23 novice endoscopists, 18 second-year trainees, and 13 expert endoscopists. They were asked to point with the endoscope tip to 20 numbers in the model as quickly as possible using torque, single-hand small/large wheel manipulation (SHSW), and retroflexion techniques. Their mean times (t20) were compared to determine if the model could distinguish different levels of expertise. Subsequently, 14 novices trained for eight short sessions, and the pre-training and post-training t20 were compared. Nine novice endoscopists received no training and were retested after 4 to 6 weeks (controls).

Results Experts had faster t20 than second-year trainees, who were faster than novices, for all three techniques ($P < 0.001$). After eight sessions, the mean t20 for novices improved from 112 to 66 seconds for torque, 144 to 72 seconds for SHSW, and 108 to 63 seconds for retroflexion, (all $P < 0.001$). Their t20 were equivalent to second-year trainees. Improvement in t20 was also seen with the control group, but total reduction was less than for the training group.

Conclusions The VTM1 distinguished varying levels of expertise for all techniques, suggesting that it is a valid tool for assessing endoscope manipulation skill. A short curriculum improved novices' manipulation skills faster than traditional practice.

Introduction

Competence in esophagogastroduodenoscopy (EGD) is required for gastroenterology trainees. Manipulation of the gastroscope is a basic skill required for gastroenterology trainees and one of many skills, such as knowledge about sedation, pathological recognition, and ability to communicate, required to be competent at performing EGD [1, 2, 3]. Traditionally trainees learn endoscopy by apprenticeship and must perform a number of cases to attain competence [4]. However, this has fallen out of favor and trainees now must be assessed for competence. In Thailand, the endoscopic competence of gastroenterology trainees is assessed by using a combination of total number of procedures performed along with number of assessed procedures.

Although there are training courses using simulation models for basic endoscopic skills [5, 6, 7], in many countries, including Thailand, there is no training curriculum to develop these motor skills for novices. Most frequently, novice endoscopists train on patients, under expert supervision, in a step-wise manner from observation, partial endoscope handling, to fully performing the procedure. Subsequent skill development usually occurs as a passive process as they perform more procedures. However, there is increased risk of complications when trainees who are not yet competent perform these procedures. In surgery [8], and many other professions involving motor skill-related activity, from flying airplanes [9] to competing in tennis, training is often done in a safe environment before performing in real life. The training environment allows for deliberate practice, or drills, that increase trainee skill level in that activity.

Although there are publications about training models for endoscopy [10, 11, 12], there is still a lack of easily affordable, commercial training tools or a curriculum to help novices improve their endoscopic skills outside of clinical practice. Such tools may speed up acquisition of basic skills and would also be beneficial for patient safety. Rapid acquisition of basic endoscope manipulation skills may also help novice endoscopists progress more rapidly to more advanced training, such as endoscopic retrograde cholangiopancreatography (ERCP), during their limited training period. Many mechanical [12] and virtual training tools [13, 14, 15] have been shown to be useful for training basic endoscope manipulation, but they are often limited due to their cost [16, 17, 18] and porcine models can be limited by preparation details (ex vivo) and ethical issues of using live animals (in vivo) [19].

In this study, we used a simple and inexpensive training model, Varix Trainer model 1, and an eight-session curriculum with deliberate practice to see if endoscope tip control with torque, single-hand small/large wheel manipulation (SHSW), and retroflexion can be improved. The Varix Trainer is a set of three training models, aimed at progressively allowing a trainee to practice endoscopic skills required in treating esophageal and gastric varices in a controlled training environment. All the Varix Trainer models were developed to be lightweight and easily affordable so that they can be made available even to trainees in low-resource countries, along the lines of the concept of design for extreme affordability initiated at Stanford's Design school [20]. In this study, we used model 1 of the set, which is the model designed for training basic gastroscope-manipulation skills needed in variceal therapy, namely torque, SHSW, and retroflexion. In the curriculum, we particularly focused on training with using the left hand to control the small and large wheels (SHSW) because this skill was observed to be used less often than torque in daily clinical practice by F1 trainees. It is possible that this technique is harder for Asian trainees who have smaller hands compared with taller Western endoscopists and whose fingers do not reach easily across the handle to manipulate the wheels. Therefore, trainees with smaller hands may prefer to use torque to move the endoscope rather than controlling the wheels with their left hand. However, this technique is important for more complex therapeutic procedures in the future, and as a result, we wanted them to be competent in SHSW as one of the core maneuvers in the curriculum.

However, before the Varix Trainer model 1 can be accepted as a training device, it should be validated. There are different types of validation for a training tool [10, 21]. One method of validation would be to demonstrate that the tool can differentiate levels of expertise in essential skills relevant for a particular task and that the outcomes measured correlate with the level of the expertise (construct validity). This would suggest that the tool captures and measures essential skills needed for the task accurately. In this study, the Varix Trainer model 1 was used to see if it could differentiate between skill levels of first-year trainees (F1), second-year trainees (F2) and staff (expert) for validation. After construct validation of the model, a short training curriculum with deliberate practice was taught and tested to see if training on the model could improve these skills over a short period (content validation).

Methods

Study population

First-year (F1) gastroenterology trainees from Gastroenterology Fellowship training centers in Thailand, including Ramathibodi hospital, Siriraj hospital, King Chulalongkorn Memorial Hospital, Rajavithi hospital, Vajira hospital, Phramongkutklao

Hospital, Srinagarind Hospital, and Nanthana-Kriangkrai Chotiwattanaphan Institute of Gastroenterology and Hepatology, were enrolled. All these training institutions have been certified by the World Federation Medical Education (WFME). Gastroenterology training in Thailand requires 2 years of training and EGD is the first procedure that the trainees learn, starting in Year 1. Second-year (F2) gastroenterology trainees were also recruited from the same institutions, and were seen as partially-trained endoscopists (between novice and expert levels), with good experience in EGD. Expert endoscopists (experts) were also enrolled and were defined as having performed EGD for more than 1500 cases and were recruited from the endoscopy trainers/staff at each institution. These experts also performed advanced endoscopies in their clinical practice including ERCP, endoscopic ultrasound (EUS), endoscopic submucosal dissection, or per-oral endoscopic myotomy. F1 who were in the control group were allowed to perform endoscopy as normal according to their usual schedule. Some F1 trainees had been taught gastroscopy in another 7-day short course and some had prior hands-on experience (generally up to 50 procedures) outside of their training program (▶ **Table 1**). In Thailand, because trainees often have to wait for an available training space in gastroenterology, many would be allowed to start performing supervised endoscopies in the district general hospitals under the local gastroenterologists.

Equipment

The Varix Trainer model I is made out of polyvinyl chloride-covered cardboard and is lightweight, moderately waterproof, affordable, and inexpensive. The model consists of a long tube attached to a box (▶ **Fig. 1**). Inside the box are two double clockfaces, one positioned forward from the scope and the other behind the scope (▶ **Fig. 1** right and left). These clockfaces contain two sets of colored numbers and can be used as targets during the training. The model was developed by one of the authors (TK) as part of a box set, the Varix Trainer set, which also contains models 2 and 3 for endoscopic band ligation and gastric varix injection training. Each of the models were adapted following hands-on testing of earlier versions using both experts and novices and the final design for commercial production was created by a design company.

▶ **Table 1** Experience level of first-year gastroenterology trainees (F1) at the start of the study.

Experience level	F1 intervention (n)	F1 control (n)
Novice	2	2
0–10 cases	4	1
10–50 cases	1	4
> 50–100 cases	2	2
7-day hands-on simulation course (novice)	5	0

Study design

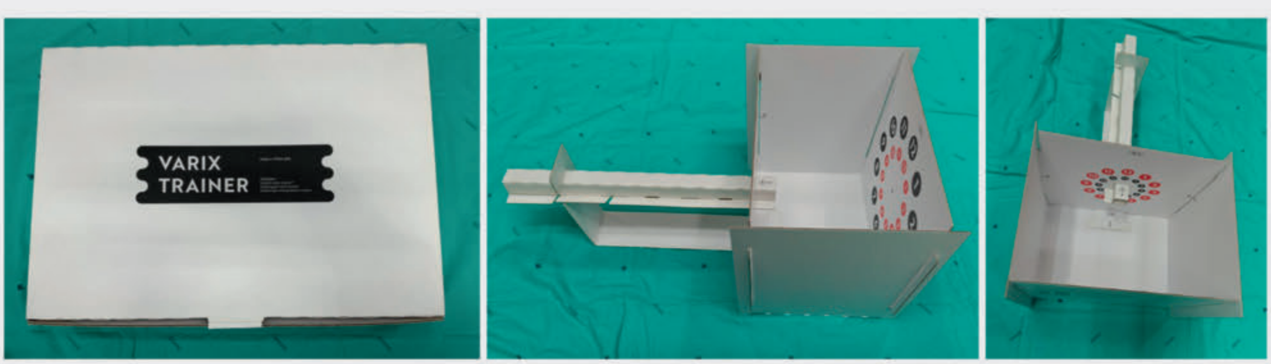
Part 1: Validation of the Varix Trainer model 1 for measuring gastroscope-manipulation skills

From August 2022 to January 2023, we enrolled 23 F1, 18 F2, and 13 experienced staff (expert) endoscopists to use the Varix Trainer model 1. Each endoscopist was asked to perform a test by using the endoscope to point to 20 pre-randomized numbers using each of the three specific endoscopic skills (torque, small wheel, and retroflexion techniques) as quickly as possible. Each skill was tested three times with different pre-randomized numbers. Time to point to 20 numbers (t20) was recorded and these numbers were compared between endoscopists with different levels of experience.

Part 2: Testing effectiveness of the training curriculum in improving F1 gastroscope-manipulation skills

F1 were divided into two groups with one group training with a curriculum and the Varix Trainer model 1 (F1-training group) for eight sessions. In the other group, F1 acted as controls (F1-control group) and did not receive any curricular training. The F1-control group trainees performed t20 at their entry into the study (pretest) and after 4 to 6 weeks similar to the F1-training group (post-test).

The trainees were not individually randomized into training and control groups, but were selected according to their training institutions. Training institutions that had previously used



▶ **Fig. 1** Varix Trainer model 1, boxed set.

the Varix Trainer in other aspects (Varix Trainer models 2 and 3 for esophageal varix banding and gastric varix glue injection) were selected for the training group and institutions that had not used the Varix Trainer set before were selected for the control group. This was to ensure that the Varix Trainer was available for testing at the site and testing and training started in the intervention group as close to the start of the clinical training year as possible. In addition, it ensured that the hospitals in the intervention group were confident in setting up the model and setting aside time for training, because the intervention group would be using the model more frequently. The intervention group consisted of trainees from Ramathibodi Hospital, Siriraj Hospital, King Chulalongkorn Memorial Hospital, and Rajavithi hospital, and the institutions in the control group were Phramongkutklao Hospital, Srinagarind Hospital, and Nanthana-Kriangkrai Chotiwattanaphan Institute of Gastroenterology and Hepatology.

The primary objective of our study was to assess whether the Varix Trainer model 1 could distinguish levels of expertise between F1, F2, and expert endoscopists for these three specific skills. The secondary objective was to assess whether curricular training with the Varix Trainer model 1 improved these specific skills in F1 over a short period of time. The flow chart of the study design is shown in ▶ **Fig. 2**.

The research was approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University, and the Ethics Committees in each respective training institution.

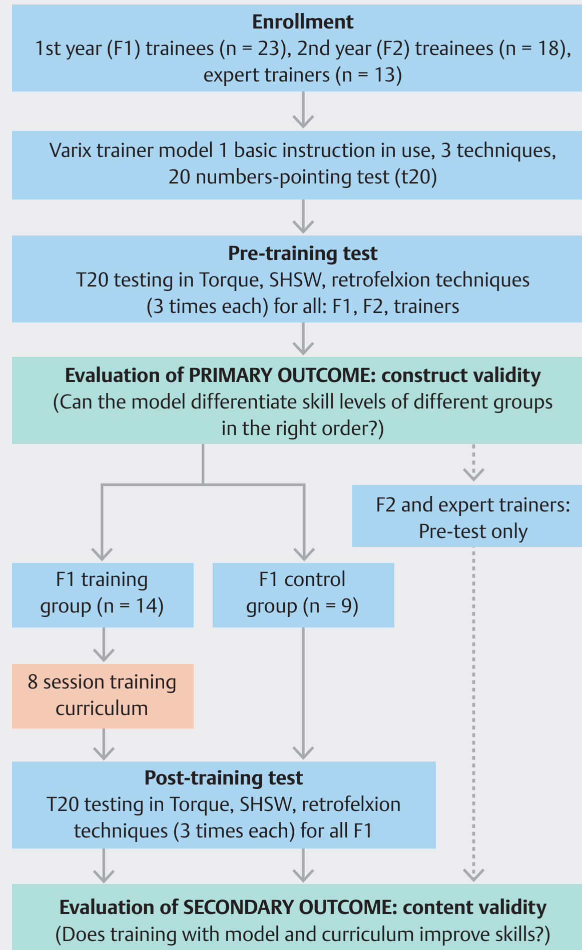
Using the Varix Trainer model 1

All participants were shown how to use the model, with the expert trainer(s) for each institution being instructed by the author and model developer, TK, and the trainees being supervised by the expert trainers in their institution or by TK. All participants were allowed time to use the model, warm up, and get used to the model before testing. F1 in both the training and control groups were also instructed on basic manipulation techniques before testing.

To perform the torque technique, participants were asked to insert the scope 50 cm into the model and maintain this distance throughout the test. They were asked to manipulate the endoscope by torqueing and upward tip deflection with their left hand. A small, blunt accessory such as a closed biopsy forceps or a needle sheath was extended out from the gastroscope for 2 cm and used as a pointer for the numbers. The tip of the pointer did not need to touch the numbers but should cover the center of the numbers as seen on the output screen.

For the SHSW technique, a colleague was asked to hold the scope tight and fix it so that it could not be torqued. Participants were asked to control the endoscope tip with their left hand only, using both the small and large control wheels, and point to the called-out numbers with the blunt accessory as before.

For the retroflexion technique, the participants were asked to retroflex to face the double clockface on the back panel. They were allowed to use both torque and wheels to move the scope and to touch the numbers with the tip of the accessory.



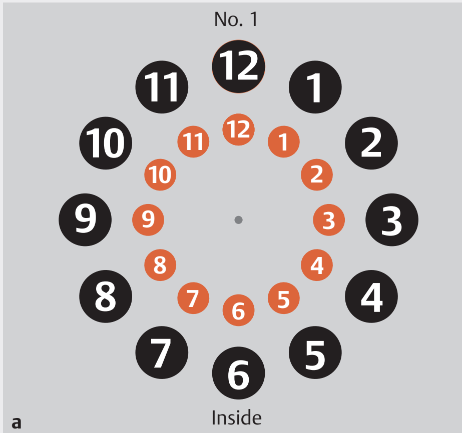
▶ **Fig. 2** Study design.

During t20 testing, a colleague would call out the number and the participant would use the accessory tip to point to a number on the clockface (▶ **Fig. 3a**), or touch in the retroflexion technique, before moving to the next number. These same three sets of pre-randomized numbers were used for testing before (pretest) and after training (post-test), as shown in ▶ **Fig. 3b**.

Curriculum (Part 2 of the study)

The curriculum was designed by TK based on teaching endoscopy for more than 10 years using principles of deliberate practice and from the results of pilot tests of the drill exercises.

The curriculum consisted of eight 20-minute training sessions, with the first and last sessions mainly involving testing of the trainees. This design was thought to be most flexible to fit into the timetables of working trainees who were at different institutions but still able to deliver the training time needed for skill improvement. The principles of deliberate practice were used in the design of the curriculum because that is the accepted method to achieve mastery in many fields, including sports and music at international levels [22]. Deliberate practice: 1) in-



b

Pre-test 1		Pre-test 2		Pre-test 3	
1B	10B	6B	9B	3B	5R
2R	7R	9R	2R	9R	8B
7B	12B	12B	8R	4B	5B
9B	1R	1R	4B	1B	11R
11B	9R	11R	10R	10R	2B
4R	3R	3R	6R	1R	6R
2B	6B	5B	3B	4R	12B
4B	10B	1B	10B	10B	7B
11B	5R	7B	7R	7R	2R
3B	12R	4R	5R	3R	11B

▶ **Fig. 3** **a** Forward-view double clockface in Varix Trainer model 1 (left). **b** Pre-randomized numbers used for testing. R stands for the red color and B for the black color on the double clockface.

cludes established techniques for training designed by experts; 2) demands near-maximal effort because training occurs at just beyond trainee comfort zone, with the training repeated and adapted to the increasing skill level; 3) and well-defined, specific training goals are required for some aspect of the performance (not overall performance) to achieve small incremental improvements; 4) requires full attention of the trainee during training; 5) involves feedback and modification according to feedback, with early feedback usually coming from the teacher but later feedback can be by self-monitoring; 6) involves improving mental representation with improving skill; and 7) requires that teachers should teach beginners with the correct fundamental skills to prevent the need to relearn those skills later [23]. However, in endoscopy training, unlike professional sports or international-level music, there is currently no established assessment of mastery (only of competence) and no established training method to achieve mastery, and so, only the principles of deliberate practice can be used to design the curriculum.

The sessions were designed to be approximately 20 minutes for three reasons. It was thought to be the amount of time the trainees could spare to practice in their working day; it was long enough to maintain the concentration needed to improve their skill despite their working schedule; and finally, the training would not be so long or complex as to produce cognitive overload because each session worked on a particular aspect of endoscope manipulation. Each session would build upon the previous sessions. Although many training curricula/hands-on workshops have been scheduled as a 1- to 14-day courses, it was thought that having multiple training sessions integrated into the working timetable would be the easiest way to apply the training to many institutions and it would also be in line with deliberate practice where mastery of skill requires repeated practice over a long period of time during a trainee's career [22].

The eight training sessions included specific drills, as well as other important aspects of gastroscopy tip control, such as proper endoscope grip according to an endoscopist's hand size. Each session included a recap of the previous session and also progressively increased the complexity of the drills. The drills were exercises with a set number of patterns. Drills, exercises, or repeated movements are used in many training schedules in both sports, such as golf, tennis, swimming [24], and martial arts, and music. Repeated movements allow a trainee to correct their movements, find the most efficient movement, and achieve automation. The initial two to three sessions were supervised by expert trainers in each respective hospital, but the later training sessions could be performed by the trainees independently using written instructions, once the trainees were able to self-monitor their performance, because the later sessions only involved a change in sequence of number-pointing.

The sessions were run once or twice per week or could be limited to one session every fortnight, depending on the workload and endoscopist availability in each hospital. They were asked not to run through the sessions more rapidly, to allow time for neurological pathway strengthening, which is thought to be important for increasing efficiency and memory for motor skills. Improved memory retrieval is thought to be related to automatization [25], and repeated interval practice has been shown to improve long-term memory [26] as well as is sleeping between learning sessions [27]. T20 testing after training with the curriculum was performed (post-test), testing each skill three time, as before, for each endoscopist.

The curriculum focused mainly on the SHSW technique because that was thought to be the most difficult technique for novices and often not used by trainees with small hands due to the difficulty of reaching across the control wheels. The SHSW was considered a fundamental skill, useful for more advanced techniques [28], and as part of deliberate practice [23], we did not want the trainees to have to relearn this skill at a later stage.

Torque and retroflexion were practiced intermittently in the curriculum because these techniques were picked up easily in the pilot tests of the curriculum once the concept and the basic techniques had been explained and practiced.

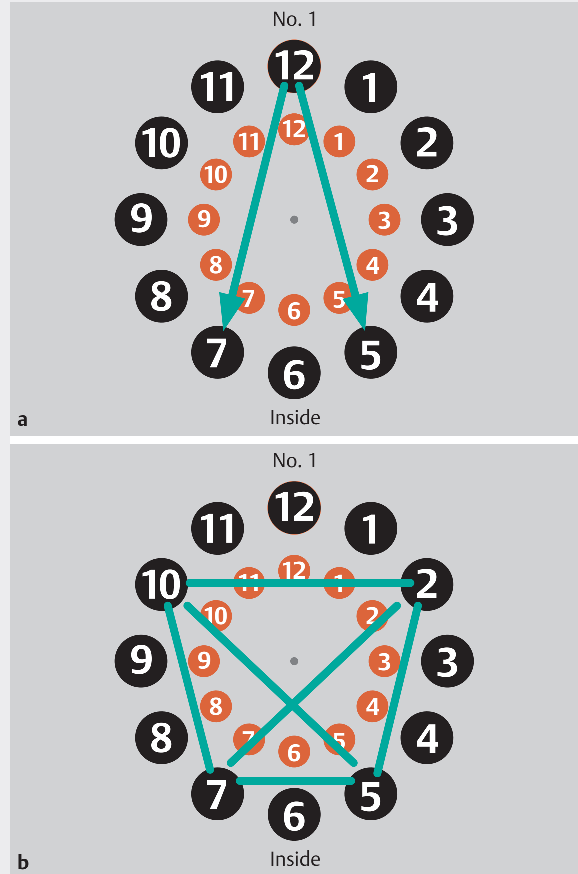
Sessions 1 and 8 were mainly informative and included completing questionnaires and the pretests and post-t20 tests. Sessions 2 to 7 were training sessions and composed of specific drills for deliberate practice, such as slow-single sequence drill and boxed-x drill (▶ **Fig. 4**).

Specfic drills

Drill 1 was SHSW slow-single-sequence (SSS drill). This drill, as the name shows, asks the trainee to deliberately slow down so that they can focus on finding the most efficient hand movements for tip deflection. There is no pressure to perform the movement fast, which is a source of cognitive load. Drill 1.1 was for true novices, with tip deflection 12 o'clock to 6 o'clock and back, and 3 o'clock to 9 o'clock and back to learn about each control wheel movement separately. Drill 1.2 was tip deflection from 12 o'clock to 5 o'clock and 7 o'clock, to start practicing the most difficult tip deflection, as found from pilot tests and questionnaires at the end of this study (data not shown). Two numbers are used in this sequence to vary the target which is thought to improve mental representation. Drill 1.3 was other numbers: from 12 to 10 or 2 o'clock and 6 o'clock to 10 and 2 o'clock. Drill 2 was eyes-closed movement (ECM drill). This drill was a sandwich drill, in that the trainees were asked to perform the number-pointing with their eyes opened, then eyes closed (opening at the end to check their final position), and then with their eyes opened again. This drill is useful for novices because it forces them to memorize and retrieve the hand movements for certain tip deflection directions, and helps with chunking the action and automation. The two eyes-open drills on either side allowed trainees to adjust their movements and commit them to memory. The drills were repeated until the correct location of the scope tip can be achieved.

Drill 3 was for triangular movements. This was where three numbers were used and the trainee was asked to perform a triangular movement of the scope tip to each number. This drill increases complexity of tip movement from the SSS drill. Drill 4 was boxed-X drill. This is where four numbers were used (ideally 2,5,7 and 10 because these are often the most difficult numbers to point to) with the directions between the numbers being to make a box with an X inside it. The trainee was asked to move the scope tip around these numbers for training. Once the trainee was comfortable with pointing at these numbers, they could move on to Drill 5. That was fast movement, in which they were asked to progressively increase their speed, particularly in the boxed-x direction, with the possibility of having a colleague call out the numbers to increase the immediacy of number-pointing.

Each drill focused on difficult endoscope movements that had been identified during pilot tests. The drills were repeated at least 10 times, and five times during the recap phase, so that a trainee could pick up the skill with continued practice. Consolidation of learning from previous sessions, repetitive training, target variation, and interleaving were integrated into the sessions to improve retention and retrieval of motor skills [26, 29, 30].

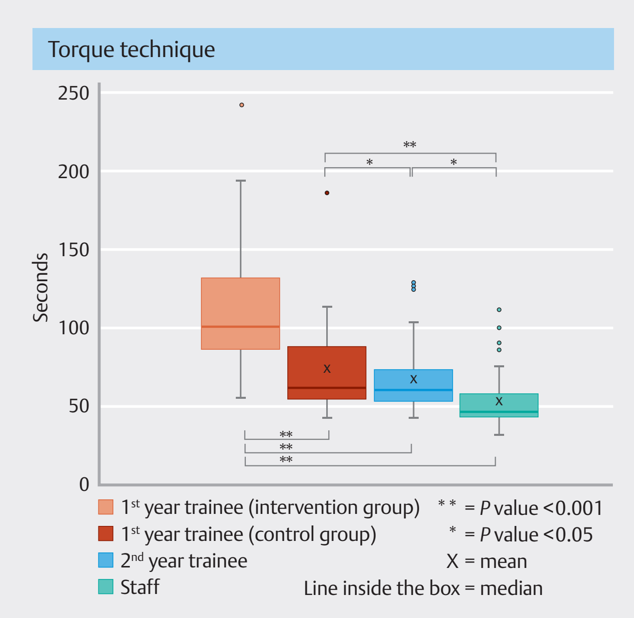


▶ **Fig. 4** **a** training drill 1, slow single sequence (SSS). **b** training drill 4, boxed-x sequence.

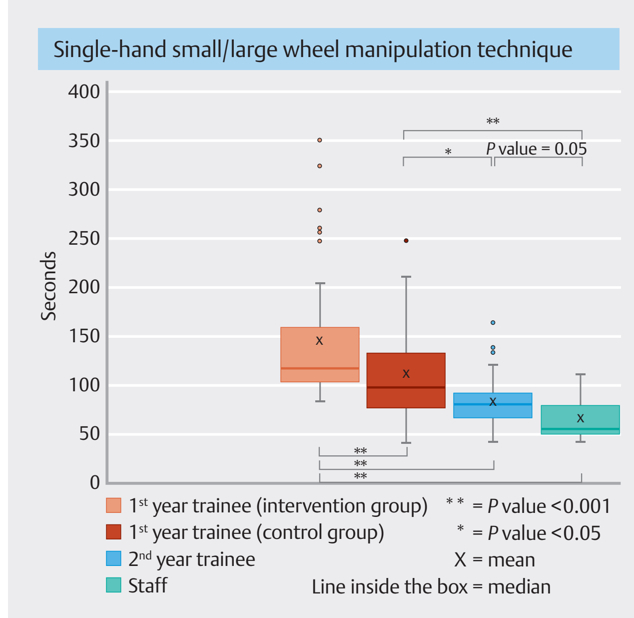
At the end of the curriculum, the F1-training participants completed a questionnaire about their confidence in performing the three techniques and ask for their recommendations regarding use of the Varix Trainer model 1 curriculum in future Gastroenterology Fellowship training.

Statistical analyses

All statistical analyses were conducted using STATA 17.0 and $P < 0.05$ was considered statistically significant. Characteristics of subjects were described by mean and standard deviation (or median interquartile range) for continuous data, and frequency and percentage for categorical data. In Part 1 of our study, we used multilevel mixed-effects linear regression to demonstrate that the t20 test using model 1 of the Varix Trainer could differentiate skill levels between F1 (intervention and control groups), F2, and experts for these three specific skills. Because this was the primary objective of our study, statistical calculation using the t20 times from a pilot test showed that the number needed for each arm was at least eight. For Part 2 of our study, we also used multilevel mixed-effects linear regression with random intercept and fixed slope to compare skill levels



▶ **Fig. 5** Graph showing t20 results for the torque technique. (Box and whisker plot shows results of t20 times. The box indicates the range IQR. The line indicates IQR. The line in the box represents the median and the asterisk represents the mean.)



▶ **Fig. 6** Graph showing t20 results for the single-hand small/large wheel technique. Box and whisker plot shows results of t20 times. The box indicates the range IQR. The line indicates IQR. The line in the box represents the median and the asterisk represents the mean.

between the training group and the control group. In addition, mixed-effects linear regression was applied for controlling confounding factors (such as hospital site (which included trainer experience), hospital EGD workload, number of EGDs performed by trainees in their 2 years, extended-hand size as measured from the tip of the thumb to the tip of the middle finger (cm), shoe size (cm), and pretest scores (as a marker of prestudy experience level) that were associated with skill levels to compare improvement in the three specific skills in F1 after training with the curriculum and the Varix Trainer Model 1 in both the training and control groups. The hospital site, extended-hand size, and pretest scores were subsequently used for adjustment because they were found to have an effect on outcome with the models.

Results

Part 1

In the first part of the study, the participants were enrolled between July and December 2022. The institutions in the training group were enrolled between July and September 2022, whereas the institutions in the control group were enrolled between October and December 2022, 4 to 6 months after training started in the training group.

Fourteen F1 were trained with the Varix Trainer Model 1 and the eight-session curriculum whereas nine F1 were used as controls. Eighteen F2-trainees and 13 experienced endoscopists were also enrolled. Because the F1 in the control group had 4 to 6 months more experience than the intervention group when they were enrolled and tested, they were analyzed as a separate group.

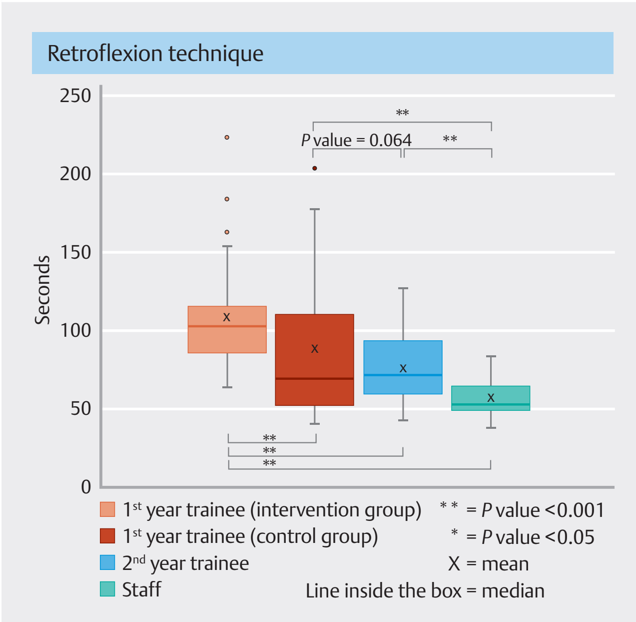
The results showed that for torque (▶ **Fig. 5**), SHSW technique (▶ **Fig. 6**), and retroflexion (▶ **Fig. 7**), the t20 time was statistically significantly different between all groups (the only nonsignificant comparison was between F2 vs F1-controls for retroflexion $P = 0.64$). As expected, the expert endoscopists were the fastest, then F2, then the F1-control group who had 4 to 6 months of clinical experience, and the slowest was the F1-training group who were tested at the beginning of their training.

Part 2

After performing the t20 tests for each technique, the F1-training group practiced with the Varix Trainer model 1 according to the curriculum for 6 to 12 weeks, between August and September 2022. The F1-control group were enrolled between October and December 2022 and completed their post-test t20 between December 22 and February 2023.

After training for eight sessions, the F1-training group improved their t20 times for all three specific skills. The mean torque t20 improved from 112 seconds to 65 seconds, the SHSW t20 improved from 144 seconds to 72 seconds, and retroflexion t20 from 107 seconds to 63 seconds ($P < 0.001$ for all three techniques). After adjusting for training site (hospital) and extended-hand size, the difference in t20 after training remained statistically significant for all techniques ($P < 0.001$).

In the F1-control group, the t20 also improved significantly for all three specific skills. Mean torque t20 improved from 80 seconds to 67 seconds ($P < 0.05$), mean SHSW t20 from 116 seconds to 75 seconds, and mean retroflexion t20 from 88 seconds to 65 seconds with $P < 0.001$ for both of the latter times.



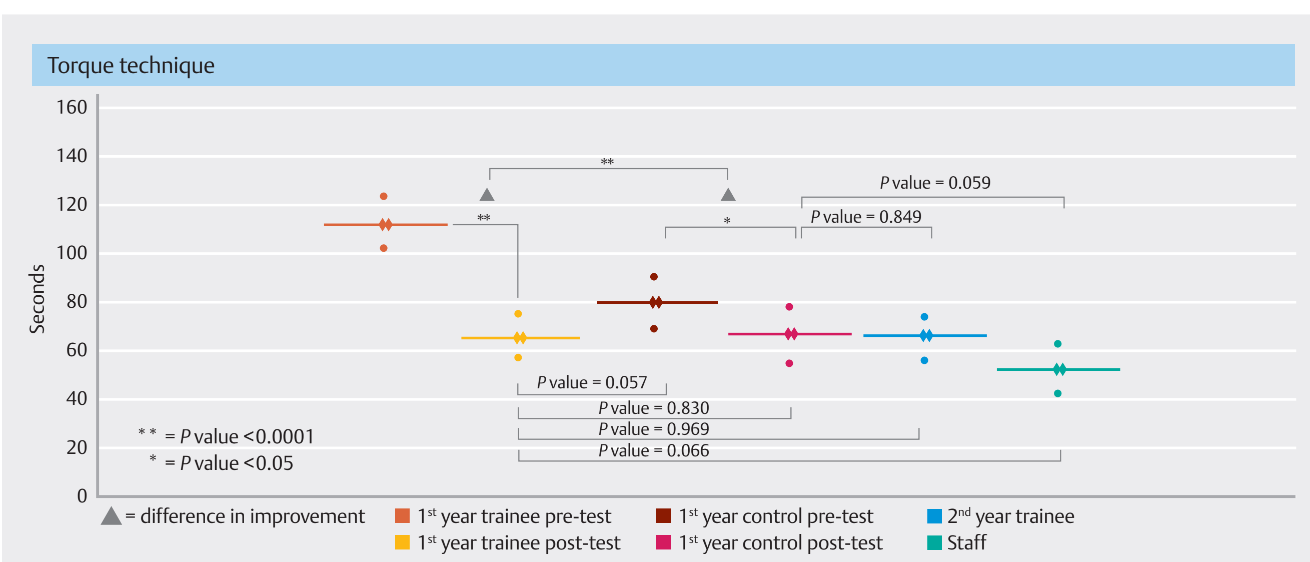
▶ **Fig. 7** Graph showing t20 results for the Retroflexion technique. Box and whisker plot shows results of t20 times. The box indicates the range IQR. The line indicates IQR. The line in the box represents the median and the asterisk represents the mean.

After adjustment for training site and hand size, the difference in t20 between pretests and post-tests for torque became non-significant ($P = 0.54$), whereas SHSW and retroflexion remained statistically significant ($P < 0.001$).

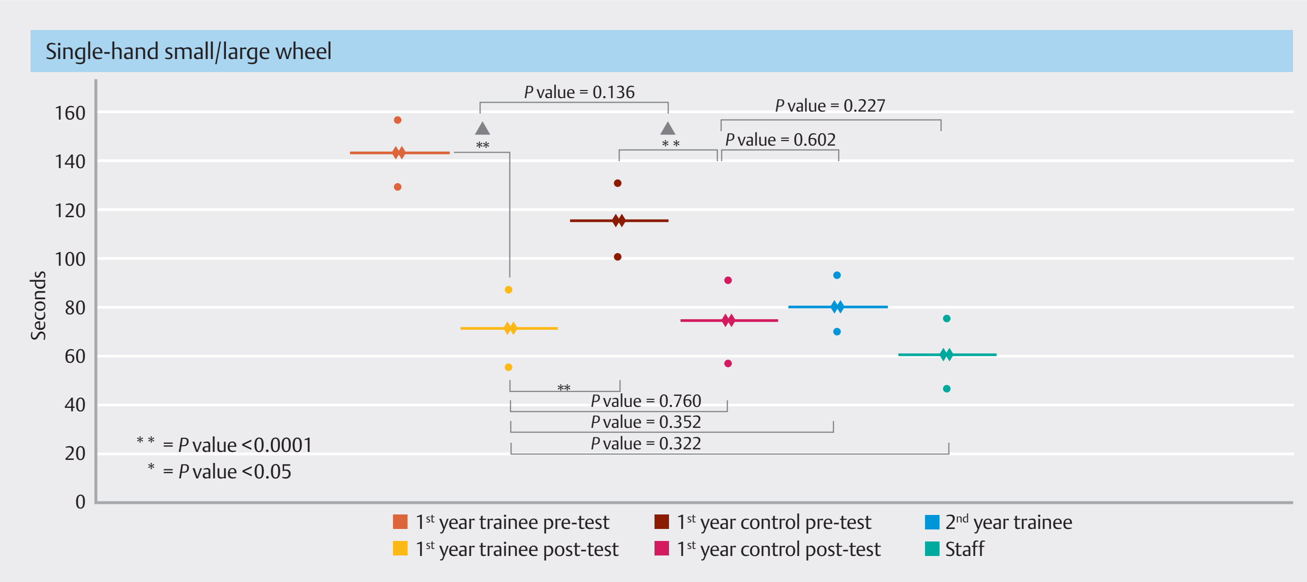
The level of improvement was greater in the F1-training group compared with that seen in the F1-control group for all three skills. In torque technique, The F1-training group t20 improved by 46 seconds, whereas the control group improved by 9 seconds ($P < 0.01$ for the difference in improvement). For SHSW technique, the t20 improvement for the F1-training group was 72 seconds, whereas the F1-control group improvement was 38 seconds ($P = 0.136$). For retroflexion, the t20 improvement for the F1-training group was 44 seconds, whereas the control group improved by 22 seconds ($P = 0.104$). Although only the improvement in the torque was statistically significant different between the two groups, the improvements in the SHSW and retroflexion techniques for the F1-training group were much better than for the control group in absolute numbers, as shown in ▶ **Fig. 8**, ▶ **Fig. 9**, and ▶ **Fig. 10**.

The post-test t20 for the F1-training group, which was done early in the training year, was faster in all three skills than the pretest for the F1-control group which was performed later in the training year. However, there was no statistical difference when the post-test t20 s for all three techniques were compared between the F1-training and the F1-control groups. The post-test t20 for these two groups were also statistically no different from the times achieved by the F2 group in the three skills, with the mean t20 of the F1 groups actually slightly better in absolute numbers for the SHSW and retroflexion techniques (as shown in ▶ **Fig. 8**, ▶ **Fig. 9**, and ▶ **Fig. 10**). Although the mean post-test t20 for the F1-training was not statistically significantly different from the experts, in absolute numbers, the expert scores were better than for all other groups in all three techniques.

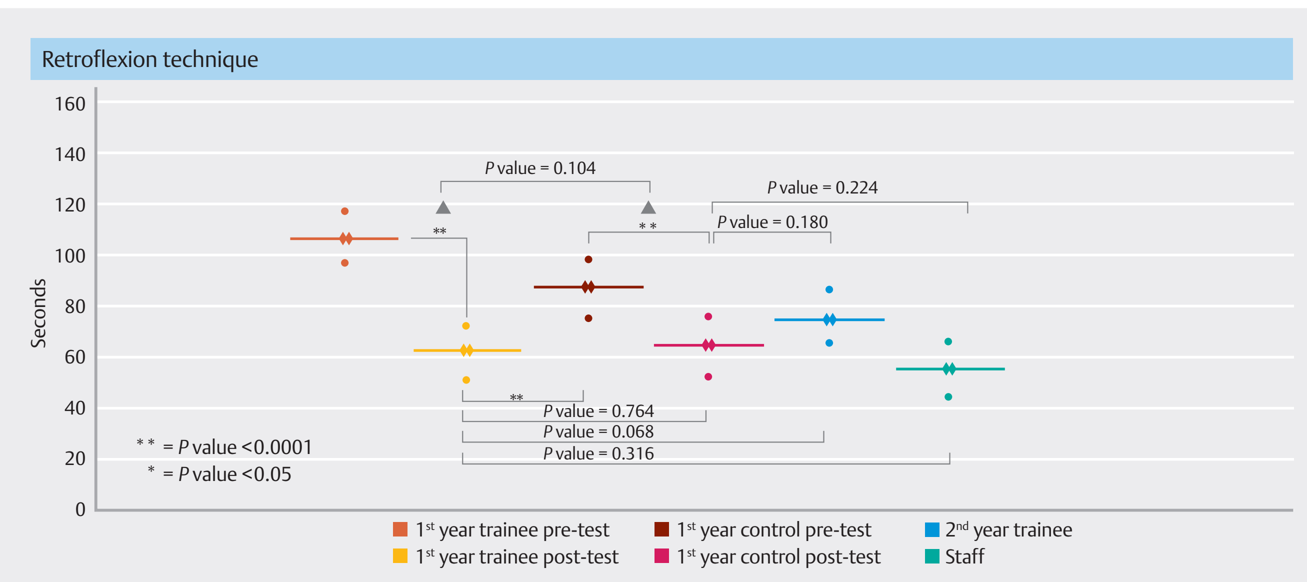
The F1 post-test t20 times were adjusted for pretest values (as a marker of different experience levels in the F1 groups), hospital site, and extended-hand size, as shown in ▶ **Table 2**. The results of this analysis showed no statistical difference between the two F1 groups. After adjustment, the t20 time for the training group were slightly slower than the control group in the torque technique by a mean of 3.5 seconds, but faster in the SHSW and retroflexion techniques by 7.4 seconds and 11.6 seconds, respectively.



▶ **Fig. 8** Post-training torque technique results. (Pretest vs post-test F1 groups and F2, experts).



▶ **Fig. 9** Post-training single-hand small/large wheel (SHSW) technique results. (Pretest vs post-test F1 groups and F2, experts).



▶ **Fig. 10** Post-training retroflexion technique results. (Pretest vs post-test F1 groups and F2, experts).

The results of the questionnaire completed by the F1-training group after completing the curriculum showed that the trainees had increased confidence in performing these three techniques, as shown in ▶ **Fig. 11**. Furthermore, trainees also suggested that it should be taught, with 50% saying it should be an incorporated as a standard part of the fellowship training program, 28.5% saying it should be taught by the institution's trainers as an addition to the program and 21.5% saying it should be practiced by the trainees in their own free time as shown in ▶ **Fig. 12**. Four experts who were trainers and supervised the F1-training group in this multicenter study commented that they liked the study curriculum and supported its use as part of the training for a fellowship program in the future.

Discussion

Endoscopic control is a basic skill needed for EGD competence. Rapid acquisition of endoscopy manipulation skills would be beneficial for patient safety and further training in colonoscopy and ERCP. However, at present, there is no standard curriculum in Thailand for training endoscopy manipulation skills. This study is the first multicenter study that tested a new training tool, the Varix Trainer model 1, and used an eight-session training curriculum to improve these skills. The three core skills in EGD trained in this study were torque, SHSW manipulation, and retroflexion. Previous studies have shown that training improves endoscope tip control [10] but very few of these studies

▶ **Table 2** Post-test times for F1 groups, adjusted for pretest values, hospital site, and hand size.

Technique	F1 group	Adjusted post-test t20 (sec)	*P* value
Torque	Training	66	0.635
	Control	62.5	
	Time difference	3.5	
SHSW	Training	68.8	0.298
	Control	76.2	
	Time difference	−7.4	
Retroflexion	Training	59.5	0.147
	Control	71.1	
	Time difference	−11.6	

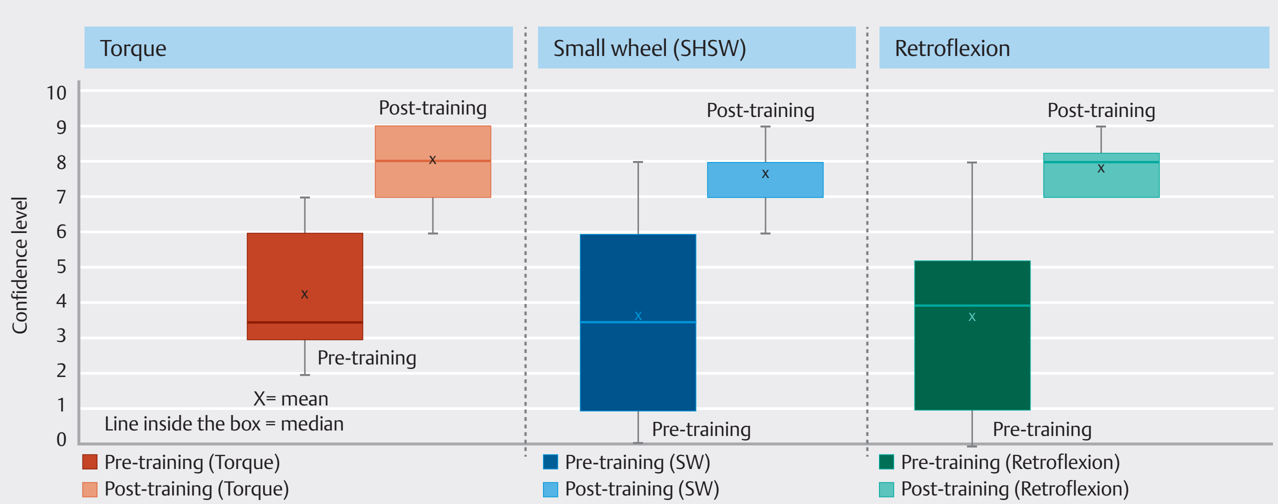
SHSW, single-hand small/large wheel.

▶ **Fig. 12** F1 recommendations for training on the Varix Trainer model 1 and the curriculum for fellowship training in the future.

have trained in all three core skills in EGD, particularly retroflexion [12], which is important for procedures such as gastric varix glue injection. In addition, none of these studies have used a set curriculum with deliberate practice for training these three skills.

Endoscopic competence has previously been inferred from the number of cases a trainee performs, but this has gradually been superseded by clinical assessments covering different aspects of endoscopy [1]. These assessments are usually performed by expert supervisors in the training institution. However, there is currently no widely available and accepted objective measurement tool for endoscopic manipulation skill for EGD. Various tools, such as virtual endoscopy simulators, can measure different aspects of endoscopy manipulation, but these tools tend to be expensive and not widely available [17, 31]. Measurement tools can be helpful as a feedback mechanism for trainees to assess their skill and practice for improvement.

In this study, we showed construct validity for the Varix Trainer model 1. We showed that it was able to correctly rank the different levels of endoscopic experience, for torque, SHSW, and retroflexion. With the t20 test, the expert group was the fastest, followed by the F2 trainees, then the F1-control group (who had 4–6 months of endoscopic experience by the time of testing), and finally, the F1-training group who were enrolled early in their training year. As predicted, the F1-training group did not have t20 times as good as the experts even after their training. As mentioned, the test was also able to differentiate the F1-control group, who by chance had 4 to 6 months of clinical training prior to entry into the study. Their scores at entry into the study were in between the early F1 trainees and the F2



▶ **Fig. 11** Trainee confidence in the three techniques before and after training. (0 = not confident at all; 10 = very confident).

trainees. This would suggest that the Varix Trainer model 1 had good construct validity for measuring endoscope manipulation skills. The F1-control group had statistically significantly faster pre-training t20 times than the F1-training group for all techniques; however, this was most evident in the torque technique. We have observed that this is the most commonly used technique for performing EGD by F1 s in their clinical practice, so we suspect that the control group had the most practice in this technique compared with other techniques by the time they took their pretest, and thus, the widest difference in t20 speed.

Subsequently we tested the model, in combination with a training curriculum of eight sessions, for content validity. That is, training with the Varix Trainer model 1 can improve endoscope manipulation skills. After training for eight sessions, we showed that for F1 trainees, t20 times for each of the three techniques improved significantly, and reached levels obtained by the F2 trainees. In correlation with this, F1 trainees felt more confident in performing these maneuvers after training. Interestingly, mean t20 times for the F1-training group were better than for the F2 group for the SHSW and retroflexion techniques, although the difference did not reach statistical significance. We have not calculated the number needed for each arm to show this difference because we did not have post-test t20 times from previous pilot tests. In general, the SHSW technique is harder than torque, and the time spent in the retroflexed position during an EGD is generally less than that in the forward-viewing position. In addition, many simple interventions, such as biopsy or injections, often are done in the forward-viewing position, so it may be that some F2 trainees were not as skillful with SHSW and maneuvers in the retroflexed position compared with torque, and specific training may be particularly useful.

In this study, the t20 for the F1-control group also improved significantly, and the post-test t20 s were no different compared with those of the F1-training group. However, the level of improvement was less compared with the F1-training group for all techniques. Because the F1-control group unfortunately did not enroll in the study at the same time as the F1-training group, the results are more open to interpretation. One interpretation is that in the usual clinical training program, the F1 trainees improve and reach a plateau in their gastroscope-manipulation skill level at around 6 months and maintain this level of skill into the second year of the program. This can be thought of as the level of competent tip control, but not mastery, which may need much more prolonged effort. Both the curriculum and the usual clinical experience may be able to achieve this level to a certain degree. Another interpretation would that exposure to the model along with basic instructions in the three techniques and the knowledge that they would be tested at the end of the curriculum stimulated trainees in the control group to practice and attend to these techniques more in their clinical practice. The 4 to 6 months prior clinical practice they had may have made it easier for them to pick up the skills once the techniques were highlighted for them. This interpretation makes it unclear whether the full curriculum was needed or not, particularly at the start of training, because complete novices (the F1-training group) may have found it difficult to pick up these skills without the curriculum.

In our subsequent analysis, we have tried to account for confounding factors, including differences in experience at entry into the study, by adjusting for pretest scores, hospital site (encompassing trainer experience and workload), and extended-hand size. The adjusted post-test results showed that the differences between the F1 training and control groups were still not statistically significant. However, it is interesting that the adjusted mean post-test times for SHSW and retroflexion were faster in the training group by 7.4 secs and 11.6 secs, respectively, while being slightly slower by 3.5 secs in the torque technique. Although admittedly this did not reach statistical significance (which could possibly be due to the fact that we did not calculate the sample size needed for this part), the results would correspond to the focus of the curriculum, which was mainly on SHSW, and improvement in the two generally less-used techniques, SHSW and retroflexion.

Nevertheless, even if the post-test t20 s for both the F1-training and F1-control groups were the same at the end, the results showed that by 3 to 4 months into their training program, the trainees who had gone through the curriculum at the beginning of their training (F1-training) had better manipulation skills compared with those who had not (F1-control) at this point. This rapid improvement would still be beneficial for the trainees because it would let them progress onto more difficult procedures, such as colonoscopy, ERCP, and EUS in their limited time in the training program.

The strengths of this study were that, first, this study was one of the few that included a training tool and a training curriculum that covered the core endoscope manipulation skills, torque, single-hand small/large wheel control and retroflexion, needed for EGD.

Second, the training tool was tested to demonstrate that it could accurately measure and differentiate skill levels of different groups from F1, to F2, to experts, for all three skills.

Third, the curriculum used was only eight sessions long, each roughly 20 minutes, including the tests at the beginning and the end, and could be easily integrated into normal clinical practice timetables. Most of the sessions did not require direct supervision but could be practiced on their own using written/diagram instructions.

Fourthly, the curriculum was designed using principles of deliberate practice [22] for developing motor skills, namely exercises focusing on specific aspects of the skill, progressing from slow and simple to more complex and faster maneuvers, developing efficient movements by starting to learn the movements slowly and only increasing speed once the correct movements were learned. In addition, other techniques for improved learning were incorporated into the curriculum, such as spacing out the sessions and interleaving the training material [29] and using objective tests as feedback for improved motor skill learning [30]. Specific drills such as ECM were used to increase memory retrieval of specific hand movements, rather than allowing use of visual tracking of the scope tip, because memory retrieval was thought to be important in automatization of a skill [25]. The curriculum was designed to focus on difficult tip movements for trainees. These difficult tip movements were identified based on previous experience with supervising trainees as well as from pilot tests using the Varix Trainer model 1, and were confirmed to be difficult by the trainees in the questionnaires that they answered at the end of this study (data not shown).

Finally, the training tool, the Varix Trainer model 1, is inexpensive, reusable, simple, lightweight, and foldable so that it is easily transportable. This means that it could potentially be widely available for training, even in low-resource countries or hard to reach/rural centers. The model costs $75 USD. This is in contrast to virtual simulators, which can cost upwards of $60,000 USD [17], and other mechanical commercial training models (with retroflexion training), which can cost around $12,500 USD [18]. Both the supervisors and the trainees who trained with it thought the model plus the curriculum was beneficial and recommended its future use as a training tool. Whether the eight sessions could be compressed or shortened into fewer sessions for convenience needs to be studied.

This study also had some limitations. First, it did not measure whether the reported improvement in endoscope manipulation resulted in measurable improvements in performing EGD in real life. Although feedback from both the trainees and supervising trainers was positive, no objective measure of transfer of skill was included in this study. Second, trainees were not individually randomized into training and control groups but intervention and control groups were selected by training institutions. This was done because it was logistically easier to ensure that the endoscopy schedule at each institution was adapted to the study with its extra training sessions. We realize that this would have added a selection bias to the results (e. g., allocation of trainee participants may be influenced by institutional/university/hospital preferences, trainee availability, or specific trainer preferences) even though all the training institutions were equally well established in Thailand and had all been certified by WFME. Third, due to logistical problems of traveling to some sites during COVID-19, the control group did not start at the same time as the intervention group, and the F1-control group would have had more practice with endoscopy. Unfortunately, we did not document the number of procedures they had performed by the time of their pretest. This confounding factor has made it difficult to interpret the final effect of the curriculum. We have tried to account for these confounding factors by performing statistical analysis adjusting for the difference in experience level by using the pretest values, hospital site, and hand size. However, the delay in entry of the F1 control group also helped to confirm the reliability of the Varix Trainer model 1 in distinguishing skill levels of endoscopists with different levels of experience. Other limitations include the fact that some F1 s had prior experience with EGD before starting training and entry into the study, and thus, the population studied was not truly novice, which may have introduced a bias. In addition, they were not supervised for the whole eight sessions, but allowed to train in the later sessions by themselves. This was because they were expected to be able to self-monitor and manage the change in number-pointing sequences by then, as well as having self-motivation to improve their skill. It is possible that these assumptions were wrong and this lack of supervision could have introduced a bias. The converse to this was that the curriculum also allowed for self-directed practice, and this also could have led to variations in skill development of individuals. We did not record the amount of time each individual practiced outside of the set curriculum time. The simple design of the training device also meant that the training required the cooperation of a colleague, to call out the numbers and also to hold the endoscope tightly when training the SHSW technique. This was a compromise to reduce costs of needing a clamp and an automated program to call out numbers and record pointing.

Last, this curriculum was designed solely to increase skills in the foundational maneuvers for gastroscope manipulation and did not cover some of the specific maneuvers important in gastroscopy, such as navigating the cricopharynx and pylorus, or shortening the scope in the duodenum. Also, the training did not aim to improve any of the other skills necessary to become a competent endoscopist, such as communication and other nontechnical skills [3]. However, the Varix Trainer model 1 could be easily incorporated into a more comprehensive course that covered these areas in the future.

Conclusions

In summary, we have demonstrated that the Varix Trainer model 1 can distinguish levels of expertise between F1, F2, and experts in core endoscope manipulation skills used in EGD (torque, SHSW, and retroflexion techniques). Training for eight sessions with a set curriculum using the Varix Trainer model 1 at the beginning of the gastroenterology training program appears to rapidly improve these skills for first-year trainees. Trainees who have trained in this way feel more confident with their endoscope manipulation and would recommend training with it. The model is inexpensive and easily transportable and its use could potentially be widely incorporated into basic training programs.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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