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Research article

The evaluation of the correlation between origami crane training and Fundamentals of Laparoscopic Surgery (FLS)

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ABSTRACT

Objective: How does making origami cranes under a dry box affect Fundamentals of Laparoscopic Surgery (FLS) scores in medical students?

Design: Four medical students from Asahikawa Medical University (tertiary hospital) participated. They made origami cranes under a dry box (origami crane training) five days per week for four weeks. The time required to make each origami crane (origami crane time) and degree of completion were evaluated. FLS scores were measured before training and on days 5, 10, 15, and 20. We examined the relationship between "origami crane training" and FLS scores.

Results: At the beginning of the experiment, none of the participants could complete the origami crane, but they were able to complete it in 31 ± 7 min on day 20. The Total FLS score was 164 ± 48 before the start of training, and 1107 ± 112 on day 20. The average scores of the students closely approached the Proficiency Level for the FLS tasks of peg transfer, loop ligation and extracorporeal ligation (103→228, 61→137, 0→259). The change over time in the average of the increase in Total FLS Score (difference from the first time and each week's score) improved significantly in four weeks ($P < 0.01$).

Conclusions: Origami crane training improved the medical students' FLS scores. We thought that origami crane training mainly enhanced hand-eye coordination and bi-hand coordination.

1. Introduction

Mastery of laparoscopic surgical techniques requires improved hand-eye coordination and spatial awareness skills [1]. Dry box (off-the-job) training is an important training tool to improve hand-eye coordination and spatial awareness skills. Suture and ligation training in a dry box is common and important [2]. Other basic techniques (e.g., grasping, lifting, pushing, pulling, pressing, and dissection) are a large part of laparoscopic surgery. However, no routine and effective training methods have been established. Fundamentals of Laparoscopic Surgery (FLS) was developed by the Society of American Gastrointestinal and Endoscopic Surgeons to teach standard cognitive and psychomotor skills to practitioners of laparoscopic surgery. The importance of standardization in training was recognized by the American Board of Surgery (ABS), which in 2008 made passing the FLS a requirement for obtaining certification in general surgery [3, 4]. The FLS consists of five tasks (Peg Transfer, Precision Cutting, Ligation Loop, Suture with Extracorporeal Knot, and Suture with Intracorporeal Knot). For all tasks, both time and accuracy are measured for performance and high scores result from tasks performed efficiently and without error. Each task has its own scoring formula based upon a combination of time and accuracy measures [5, 6]. The performance of the FLS tasks has been shown to be correlated with intraoperative performance on laparoscopic procedures [7, 8]. Creating various shapes with origami is a traditional Japanese culture. The crane, which is one of the most well-known origami forms, is not easy to create due to its complex structure (Figure 1). In recent years, some Japanese laparoscopic trainees have been trained to make origami cranes under a dry box (hereafter referred to as origami crane training). Coordinated movement of both forceps is essential to make an origami crane in a dry box, and it is considered effective for training hand-eye coordination and bi-hand coordination [9]. In the present study, we examined the impact of origami crane training on the FLS scores of medical students.

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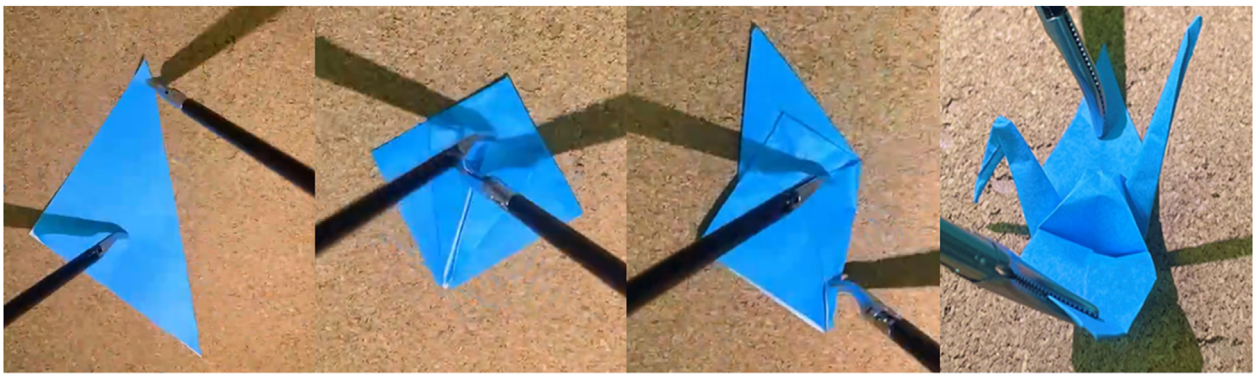

Figure 1. The process of creating a "crane" by folding paper and the origami crane score when not completed. (1) For 1–10 folds: multiply score by 0.25. (2) For 11–18 folds: multiply the score by 0.5. (3) For 19–30 folds: multiply the score by 0.75.

2. Materials and methods

This study is a prospective single-arm cohort study examining the relationship between origami crane training and FLS scores in four Japanese medical students. The study participants were four medical students who had never been trained in surgical techniques for laparoscopic surgery. They were already able to fold the origami crane using their hands. These participants underwent origami crane training five days per week for four weeks. During the period, the students were given the task of making one origami crane per day under a laparoscopic dry box (hereafter referred to as origami crane training). The paper used for the origami crane in this study was white on one side, with various colors on the other side. The dimensions were measured 7.5 × 7.5 cm. This paper is a standard paper and is not a traditional one. The training was directly started using this size of the paper without any other prior training using larger or smaller sizes of the paper. The origami crane training was terminated if the participant could not complete the origami crane in 100 min. The completed origami cranes were mutually evaluated for quality. The perfection of the origami cranes (precision, shape, and lack of scratches) was scored on a 15-point scale, and the experimenters evaluated and scored each other (hereafter referred to as the origami crane score). For the unfinished origami cranes, the score was multiplied by the degree of progress (Figure 1). The FLS performed five tasks, each scored according to the manual [5, 6]. The FLS tasks were demonstrated by the supervising physician at the beginning of this study and each participant was referred to the FLS training video. After that, each participant did the origami crane training without the supervising physician. The FLS was performed five times before the start of origami crane training (day 0) and at the beginning of each week (day 5, day 10, day 15, day 20). This study was approved by the Asahikawa Medical University Research Ethics Committee (No. 20181). Written informed consent was obtained from the medical students. The results were presented as the mean ± standard deviation of the participants. All analyses were performed using the R software program (version 3.1.2) and the EZR software program [10]. We determined that comparisons over time were necessary to determine improvement in technique. Since the FLS scores were measured at weekly, we tested them using repeated measures analysis of variance (ANOVA). It was performed to analyze the change over time in the average of the increase in total FLS score (difference from the first time and each week's score because minimize individual differences). We thought that this analysis would allow us to determine how much difference there was in the Total FLS Score increase within the origami crane training period, regardless of the individual's ability. P values of <0.05 were considered to indicate statistical significance. The authors declare no conflicts of interest in association with the present study.

3. Results

The four participants were two males and two females with a median age of 23.5 (22–24) years. All participants were right-handed. Two participants self-reported being good at video games. All participants self-reported being good at driving. Three participants self-reported being dexterous.

Figure 2 shows the crane completion rates in chronological order. The degree of completion increased over time.

Figure 3a shows the origami crane time. At the beginning of the experiment, no one was able to complete the origami crane training; from the fourth day, the task was completed within the time limit. On the 20th day, they were able to complete the task in 31 ± 7 min (Figure 3a). Total origami crane time was 1217 ± 168 min Figure 3b shows the mutual evaluation of the origami cranes.

Figure 4 shows the change over time in FLS scores: After 4 weeks of training, the average scores of the students reached a level that was close to the Proficiency Level [5] in peg transfer (Figure 4a), ligation loop (Figure 4c), and suture with extracorporeal knot (Figure 4d) (peg transfer, 90% [228/252 points]; ligation loop, 93% [137/147 points]; extracorporeal ligation, 91% [258/284 points]). The average scores of the students for precision cutting (Figure 4b) and suture with intracorporeal knot (Figure 4e) were 155 ± 20 and 329 ± 81 points, respectively (precision cutting, 77% [155/202]; intracorporeal ligation, 67% [329/488]). The Total FLS score was 164 ± 48 before the start of training, 527 ± 151 on day 5, 767 ± 240 on day 10, 822 ± 127 on day 15, and increased to 1107 ± 112 points on day 20 (Figure 4f). The Total FLS scores increased with a decreasing origami crane time, with the average scores of the students identified to be close to the Proficiency Level (1107/1373 points), and both tasks improved over time.

Figure 5 shows the change over time in the average of the increase in Total FLS Score (difference from the first time and each week's score); there was a significant difference between W1 and W4 ($P < 0.01$), and Total FLS Score increased significantly in four weeks ($P < 0.01$).

4. Discussion

In this study we examined the relationship between "origami crane training" and FLS score. The present study showed that origami crane training increased the FLS score. As noted above, FLS training is an indicator of improved laparoscopic technique, and FLS training has been

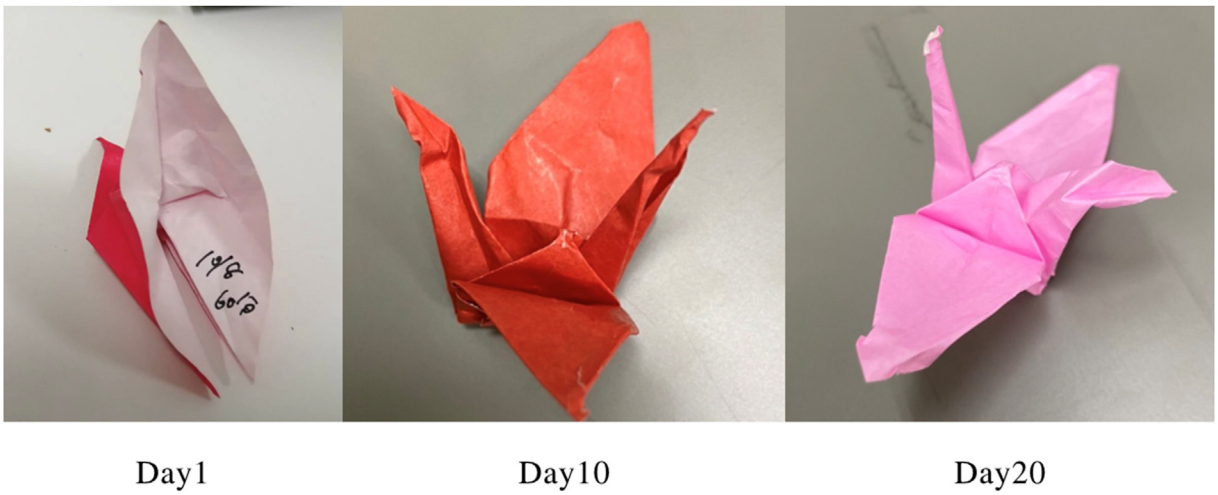

Figure 2. Images of actual origami cranes created. The perfection of the cranes increased over time.

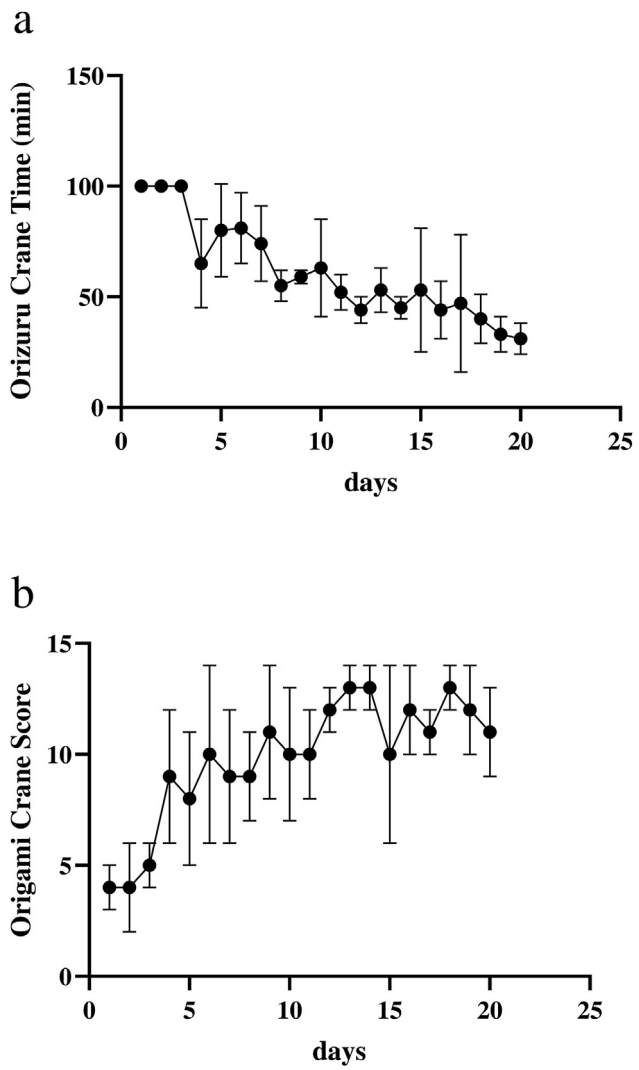

Figure 3. a: Change in the origami crane time over time. Participants were unable to fold the origami crane within 100 min until the third day, after which they gradually became able to complete the task within the time frame; on the 20th day, the time frame was reduced to 31 ± 7 min b: Change in the origami crane score over time. The perfection of origami cranes also increased over time.

reported to be associated with a significant increases in surgical scores (Lap-C) [8]. Among the skills, hand-eye coordination and bi-hand coordination are important for laparoscopic procedures [11, 12]. In addition, FLS training is thought to train coordinated movements [13]. Based on the results of this study, in which origami crane training increased FLS scores, it was hypothesized that origami crane training would improve hand-eye coordination and bi-hand coordination.

For each FLS task, the average scores of the students closely approached the Proficiency Level for peg transfer, loop ligation, and suture with extracorporeal knot, while eventually exceeding 90% after the continuation of origami crane training [5]. Laparoscopic and non-laparoscopic surgeons are reported to show significant differences in scores for peg transfer, precision cutting, and suture with intracorporeal knot [1]. In other words, scores for peg transfer, precision cutting, and suture with intracorporeal knot may reflect hand-eye coordination and bi-hand coordination, which are not important in laparotomy. In particular, peg transfer has been employed in VR simulator tasks because it provides training in hand-eye coordination and bi-hand coordination [14, 15]. The high percentages for peg transfer, which reached the Proficiency Level [5], in this study suggested that the origami crane training mainly enhanced hand-eye coordination and bi-hand coordination. Furthermore, there was no significant difference in loop ligation scores, and it was considered that there was no difference between laparoscopic and non-laparoscopic surgeons because the technique is not frequently used [1]. In this study, the average scores of the students closely approached the Proficiency Level for loop ligation and suture with extracorporeal knot [5]. Unlike the other tasks, forceps manipulation is mainly performed with one hand; thus, it is likely that the improvement in forceps manipulation through origami training and hand-eye coordination contributed to the favorable increase in the scores.

On the other hand, the percentages for precision cutting and suture with intracorporeal knot were less likely to reach the Proficiency Level [5]. Hand-eye coordination and bi-hand coordination are also important for precision cutting and intracorporeal ligation, but the operations of "dissection", "needle movement", and "ligation" themselves are unique and require practice [3]. Since precision cutting with scissors is an operation experienced in daily life, it was thought that training with origami cranes alone would not be sufficient to improve suturing, especially intracorporeal suturing, and that dedicated training and instruction would be necessary.

The Total FLS Score (difference from the first time and each week's score) increased significantly over time, and since there was a significant difference between W1 and W4, we thought that four weeks of origami crane training would result in a significant increase in the Total FLS Score. In laparoscopic procedures, it is difficult to improve and judge the

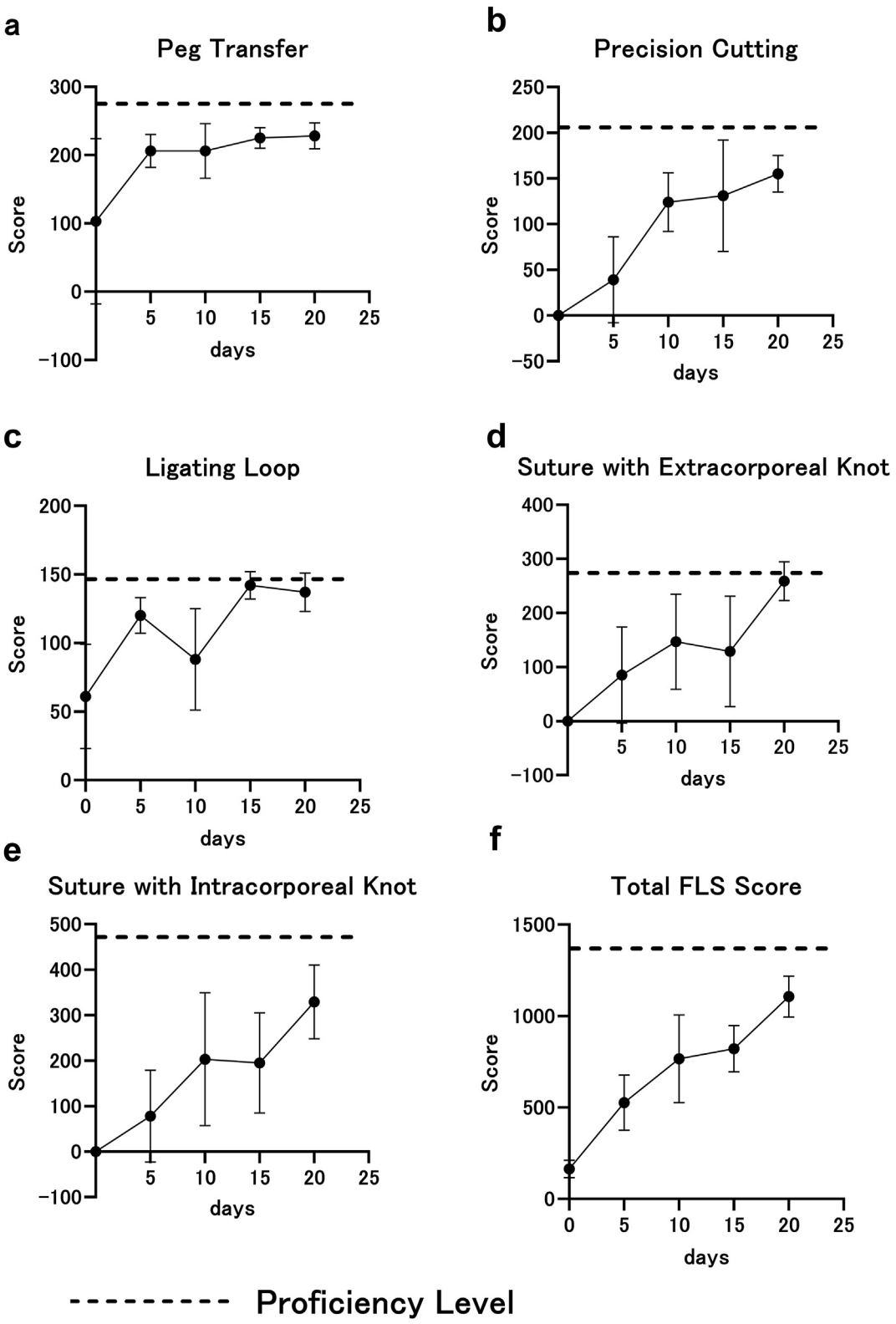

Figure 4. Change in the FLS scores over time. a: FLS scores for peg transfer increased over time. The final percentage of students reaching Proficiency Level was 90%. b: Precision cutting FLS scores increased over time. The final percentage of Proficiency Level was 77%. c: FLS scores for loop ligation showed ups and downs but increased over time. The final percentage of students reaching Proficiency Level was 93%. d: FLS score for suture with extracorporeal knot slightly decreased at week 3 but increased at week 4. The final percentage of students reaching Proficiency Level was 91%. e: FLS scores for suture with intracorporeal knot increased over time. The final percentage of students reaching Proficiency Level was 67%. f: Total FLS scores increased over time. The final percentage of Proficiency Level was 81%.

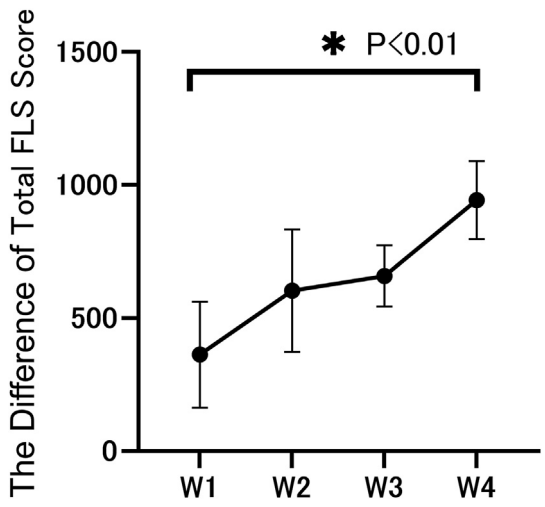

Figure 5. The change over time in the average of the increase in Total FLS Score (difference from the first time and each week's score). We tested them using repeated measures ANOVA. There was a significant difference between W1 and W4 ($P < 0.01$), and Total FLS Score increased significantly in four weeks ($P < 0.01$).

skills of novice surgeons; thus, the existence of an index such as the FLS can ensure the basics of the procedure. However, FLS devices are not widely used. On the other hand, origami crane training is low-cost and easy to introduce, as it requires only a dry box and origami. The results of this study indicate that there is a relationship between the origami crane time and the FLS score. In addition, origami crane training was found to be effective as a formalized off-the-job training. Therefore, it is thought that origami crane time will make it possible to widely and easily evaluate basic laparoscopic procedures.

Several other advantages of origami crane training can be noted. One is the simplicity of the training index. The indicators for origami crane training are the degree of completion and the time taken to make the origami crane. There is only one report on origami crane training; it has been reported to be associated with improved hand-eye and left-right coordination, reduction of tremor, acquisition of delicate technique, the ability to distinguish subtle differences in color, ability to respond to trouble [9]. This report shows that two participants created 2000 and 700 origami cranes, respectively, and that the creation time was reduced. However, there is no comparison with another index, the training effect is unknown. In this study, the origami crane score and origami crane time were set, but in daily training, the degree of completion and time to make origami cranes can also be easily checked with confidence; thus, they are considered simple indicators. Another point is that it is useful for maintaining motivation. The improvement of the degree of completion and the reduction of the time to make origami cranes may contribute to the maintenance of training motivation and it may be a sustainable training tool for laparoscopic trainees.

Making origami crane with laparoscopic forceps requires techniques for grasping and holding with appropriate force. These techniques are well suited for grasping and holding tissues in actual surgery. It has been reported that grasping, holding, detachment, and identification (color tone and layer boundaries) are improved by origami crane training [9]. Therefore, origami crane training may be useful for laparoscopic surgery in actual practice.

The training time in this study was longer than in other studies as the time required to become proficient in FLS [8, 16]. The reason may be that the participants did not practice the FLS tasks repeatedly. The results of this study also suggest that precision cutting and intracorporeal ligation require unique training, which may have resulted in a longer FLS proficiency time. The comparison of proficiency times suggests that origami crane training may be more difficult than FLS training. However, we believe that the previously mentioned advantages are important.

The present study was associated with some limitations. First, it is not known whether origami crane training is associated with improved clinical skills or outcomes. Second, this study is a prospective single-arm cohort study examining the relationship between origami crane training and the FLS scores in four Japanese medical students. The small number of participants may have caused a selection bias. There are two possible future prospects. First, it is necessary to increase the sample size and see if reproducibility can be obtained. Second, it is necessary to have trainee physicians perform the origami crane training to see if the technique can be improved using simulators and actual surgery.

5. Conclusion

Origami crane training improved the FLS scores, especially in peg transfer and loop ligation, which involve hand-eye coordination and bi-hand coordination. In addition, four weeks of origami crane training significantly increased the Total FLS Score. Therefore, we thought that origami crane training is useful as laparoscopic training.

Declarations

Author contribution statement

Tomohiro Takeda: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Tatsuya Shonaka: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Yuki Adachi; Masahide Otani; Mizuho Ohara; Chikayoshi Tani; Kengo Kita; Kimiharu Hasegawa; Yasuo Sumi: Conceived and designed the experiments.

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Data availability statement

Data included in article/supp. material/referenced in article

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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