Effect of smartphone laparoscopy simulator on laparoscopic performance in medical students

Short title: Smartphone laparoscopy simulator

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ABSTRACT

Background

This study aims to investigate if a smartphone laparoscopy simulator, SimuSurg, is effective in improving laparoscopic skills in surgically inexperienced medical students.

Methods

This is a single-blinded randomized controlled trial featuring 30 pre-clinical medical students without prior laparoscopic simulation experience. The students were randomly allocated to a control or intervention group (n=15 each) and 28 students completed the study (n=14 each). All participants performed three validated exercises in a laparoscopic box trainer and repeated them after one week. The intervention group spent the intervening time completing all the levels in SimuSurg while the control group refrained from any laparoscopic activity. A pre-study questionnaire was used to collect data on age, sex, handedness, and experience with gaming.

Results

The total score improved significantly between the two testing sessions for the intervention group (n=14, median change [MC]=182.00, p=0.009) but not for the control group (n=14, MC=161.50, p=0.08). Scores for the non-dominant hand improved significantly in the intervention group (MC=66.50, p=0.008) but not in the control group (MC=9.00, p=0.98). There was no improvement in dominant hand scores for either the intervention (MC=62.00, p=0.08) or control (MC=26.00, p=0.32) groups. Interest in surgery (β=-234.30, p=0.02) was positively correlated with the baseline total scores; however, age, sex, and experience with video games were not.

Conclusions

The results suggest that smartphone applications improve laparoscopic skills in medical students, especially for the non-dominant hand. These simulators may be a cost-effective and accessible adjunct for laparoscopic training among surgically inexperienced students and clinicians.

KEYWORDS: simulation, surgical education, laparoscopy, smartphone application, surgery

INTRODUCTION

Surgical simulations have been increasingly recognised for their value in learning and practising surgical skills in a low-risk environment.[1] Simulation-based laparoscopic training has been shown to improve surgical proficiency by imparting skills that are transferable to the operating theatre.[2] Numerous methods for laparoscopic training are available including box trainers, virtual or augmented reality simulators, animal models or human cadavers.[3] However, most of these training methods have pitfalls, such as requiring a qualified trainer or expensive equipment, highlighting the need for novel training strategies.[3]

Smartphone applications are yet to be explored as a training modality unlike other forms of simulation. SimuSurg is a smartphone application created by the Royal Australasian College of Surgeons which is aimed at simulating minimally invasive surgery and developing a range of competencies required from junior surgeons. The application consists of six activities at four difficulty levels (beginner, intermediate, advanced, and expert) with a time limit for each one. Each activity requires users to manipulate laparoscopic instruments in a virtual environment and perform different tasks such as grasping, cutting or transferring objects. The application requires the use of both thumbs to control two on-screen joysticks representing each instrument. For example, one of the advanced activities requires users to grasp a hanging thread with one instrument, cut it with the other, and avoid touching other structures which incur a time penalty. After each level, one to three medals are awarded to the user depending upon the speed with which the activity was completed.

Smartphone applications like SimuSurg have the potential to address some of the limitations posed by other simulation-based training methods. They are inexpensive, do not require specialised equipment other than a smartphone, and provide instantaneous feedback on performance. Despite this, these applications are relatively new and have not been adequately evaluated for their role in surgical training. Chalhoub and colleagues found that playing smartphone games unrelated to laparoscopy improved laparoscopic skill in 45 medical students.[4] Furthermore, a few studies have investigated a smartphone application called TouchSurgery and have demonstrated its effectiveness in training cognitive aspects of laparoscopic surgery.[5-7] TouchSurgery is designed to teach the key steps and operative decisions required for specific surgical procedures through interactive animations[7]; however, no study has investigated the efficacy of an application like SimuSurg which involves operating laparoscopic instruments in a virtual environment.

Additionally, experience with video games has been investigated for its impact on laparoscopic performance; however, the current literature is yet to reach a consensus on whether it effects laparoscopic performance or not.[9-11] Likewise, several studies have investigated the influence of personal factors including age, sex, hand dominance, and interest in surgery on laparoscopic skills but no consistent relationship has been identified.[9-11]

This aims of this study are to, firstly, determine if the SimuSurg smartphone application is effective in improving laparoscopic skills in medical students naïve to surgical training. And, secondly, to determine if age, sex, interest in surgery as a career, or experience with video games are correlated with greater laparoscopic skills.

METHODS

Trial Design and Participants

The study was conducted as a single-blinded randomized controlled trial involving medical students from Queensland, Australia. A convenience sample of 200 first- and second-year students from the Griffith University School of Medicine were invited to participate in the study via email. Participants were excluded if they had experience with a laparoscopic training kit or simulator, had performed or assisted with laparoscopic surgery in the past, or had an uncorrected visual impairment at the time of screening. Participants were consented and assigned into either the experimental or control group (1:1 ratio) using an online computer-generated randomisation schedule, balanced by randomly permuted blocks with sizes ranging from four to six.[12]

Interventions

Two identical Ethicon Endo-Surgery box trainers (Ethicon Endo-Surgery TASKit; Cincinnati, Ohio) were utilised to assess laparoscopic performance as they have been shown to correlate to laparoscopic ability in the operating room.[8] Three laparoscopic box trainer activities were chosen from a study performed by Schreuder and colleagues which validated six activities as effective training tools.[13] Three activities were chosen due to time constraints and as they each assessed a unique skill. These exercises are described in Appendix A. Briefly, exercise 1 (“beads”) involves stacking cylindrical beads on toothpicks; exercise 2 (“washers”) involves dragging washers from one end of a curved wire to the other end; and exercise 3 (“rope”) involves threading a rope through a series of loops in a zig-zag shape. All activities require both hands and have a time limit of 5 minutes. The score for each activity is the time in seconds taken to complete the activity plus any time penalties as described in Appendix A. A participant's total score for a session is given by the sum of the scores for each activity.

Students were given a 5-minute briefing session to introduce the activities and equipment. All participants performed a baseline test using the laparoscopic box trainers and an identical test after one week. Participants in the intervention group were asked to download the SimuSurg application on their smartphones and finish all the simulation activities at every difficulty level in the intervening week. Participants in the control group were asked to refrain from performing any laparoscopic-related activities during this week. Both groups were advised to avoid changing their usual habits with regards to playing musical instruments, gaming, participation in sports and textile crafts.

Data collection

During both testing sessions, an examiner who was blinded to the participant's group allocation recorded the time taken for each activity using an electronic stopwatch. The "beads" activity involved discrete time measurements for each hand, with which the scores for the dominant and non-dominant hand were recorded separately. Participants were also given a pre-study questionnaire (Appendix B) to record their age, sex, hand dominance, interest in pursuing surgery as a career, and experience with gaming. The primary outcome was participants' scores on the laparoscopic box trainer and the secondary outcome was participants' pre-study questionnaire answers.

Enrolment target

The enrolment target was calculated using the novice and intermediate scores reported by Schreuder et al.[13] The mean overall score was 1891 +/- 395 seconds for the novice group (n = 18) and 1022 +/- 352 seconds for the intermediate group (n = 14). This is a mean difference of 869 seconds (95% confidence interval [CI] = 1143 to 595). Based on these results, to achieve a statistical power of 80% and alpha level of 0.05, a minimum sample size of 6 is required.

Statistical analysis

Statistical analysis was performed in SPSS v26.0 (IBM Corporation; Armonk, New York). Since the data was not normally distributed, non-parametric statistical methods were used. We report continuous variables as medians with interquartile ranges and categorical variables as frequencies and percentages. Between-group comparisons of scores in the control and intervention group at baseline were made using the Mann-Whitney U test. Within-group comparisons of scores in the first and second sessions were made using the Wilcoxon signed-rank test. Multiple regression was used to evaluate factors associated with baseline total scores from the first session. For this analysis, pre-study questionnaire data including age, sex, interest in surgery as a career, and regular gaming (one or more times per week) were considered as the independent variables and baseline total scores as the dependent variable. Finally, for the "beads" activity, the participants' dominant and non-dominant hand scores in the first and second sessions were analyzed using the Wilcoxon signed-rank test. A p-value less than or equal to 0.05 was considered as statistically significant.

Ethics

Ethics approval was obtained via the Griffith University Human Research Ethics Committee (GU ref no: 2018/679).

RESULTS

Thirty students consented to the study and 15 were subsequently randomized into the intervention group and 15 into the control group (Figure 1) between February 2019 and April 2019. One participant from the control group and one participant from the intervention group did not complete the second testing session and were excluded from the primary analysis.

Baseline scores (first testing session) were similar across control and intervention groups for the "beads" (U = 133.00, p = 0.11), "washers" (U = 97.50, p = 0.98), and "rope" (U = 109.00, p = 0.64) activities, and total scores (U = 112.50, p = 0.51).

Table 1 shows the results of the Wilcoxon signed-rank test comparing the first and second testing session scores for the control and intervention groups. The control group did not improve significantly in the "beads", "washers", or "rope" activities, or in total scores. The intervention group did improve significantly in the "beads" and "washers" activities and total scores but not in the "rope" activity.

Table 2 shows the results of the Wilcoxon signed-rank test between dominant and non-dominant hand scores. There was a statistically significant improvement in the intervention group's non-dominant hand scores, but not in the dominant hand scores. No significant change in scores was observed in the control group.

Table 3 shows the demographic data of the two groups. Multiple regression analysis of baseline laparoscopic scores revealed that an interest in pursuing surgery as a career was significantly correlated ($\beta = -234.30$; 95% CI = -429.88 to -38.72; $p=0.02$). However, age ($\beta = -6.64$; 95% CI = -31.11 to 17.83; $p = 0.58$), sex ($\beta = -54.96$; 95% CI = -250.04 to 140.12; $p = 0.57$) and regular gaming one or more times per week ($\beta = 0.92$; 95% CI = -299.22 to 301.05; $p = 0.99$) were not significantly correlated with baseline laparoscopic scores.

DISCUSSION

Training using the SimuSurg application led to a statistically significant improvement in laparoscopic performance in surgically novice medical students, especially for the non-dominant hand. While the reason behind this effect is uncertain, it is possible that some skills taught by the smartphone simulation are transferable to the laparoscopic box trainer. For instance, the application allows users to familiarise themselves with the instruments and their functions. Users must also master the inverted control axes, where moving the hand in one direction results in the instrument moving in the opposite direction, and movement scaling, where small hand movements lead to relatively large movements in the instruments. Finally, the application requires users to adapt to the lack of depth perception associated with a two-dimensional screen. Our results suggest that novice surgeons or junior doctors may benefit from using smartphone applications as an adjunct to their initial training.

The improvement in non-dominant hand scores is corroborated in a randomized controlled trial by Middleton and colleagues.[14] They found that playing games on the Nintendo Wii (Kyoto, Japan) had a greater impact on improving non-dominant hand performance in laparoscopy than the dominant hand. This may be because the non-dominant hand is at a lower baseline dexterity level and is more likely to benefit from training.[15] This is an important finding as training the non-dominant hand helps with efficient use of laparoscopic instruments, and reduces fatigue and operative times.[16] Furthermore, a phenomenon known as the "intermanual transfer of motor skills", where training one hand increases the dexterity of the other, may serve to benefit users of the application.[15] This is demonstrated in another randomized controlled trial of 25 residents and consultants that found training the non-dominant hand improved laparoscopic performance in the dominant hand compared to untrained controls.[15] Future research is required to replicate our findings and confirm if this phenomenon occurs with the use of smartphone laparoscopy simulators.

Kolozsvari et al. found that interest in surgery was a statistically significant predictor for baseline laparoscopic ability and learning rate.[9] There is scarce literature studying the impact of surgical interest or motivation on laparoscopic skill. However, the effect of motivation on learning is well-known as motivation promotes learning and correlates to achievement.[17,18] In our study, interest in surgery as a career was strongly associated with baseline laparoscopic skill. Students that were interested in surgery may have had experience with non-laparoscopic surgical activities such as suturing or simply taken the baseline testing session more seriously.

Surgical literature is yet to reach a consensus on the influence of gaming experience on laparoscopic performance, with some studies reporting a positive relationship[10,14,19,20] and some reporting no statistically significant relationship[9,11,21-23]. However, some authors suggest that skills learnt in video games like hand-eye coordination, visuospatial awareness, and attention are transferable to laparoscopy.[19] In our study, regular gaming one or more times per week was not associated with improved laparoscopic scores. This discrepancy may be explained by the fact that most of the literature reporting a positive relationship between gaming and laparoscopic skill was performed over 10 years ago. In a contemporary cohort of medical students, it is likely that all students are adept with computers or consoles, potentially eliminating the effects of gaming on laparoscopic skill.[9]

Some studies suggest that there are sex differences in specific laparoscopic parameters including speed and dexterity.[20,23,24] The idea that males and females differ in surgical aptitudes may perpetuate gender discrimination in surgery.[20] However, other studies cast doubt on this notion. Kolozsvari et al. found no statistically significant difference between sexes in laparoscopic performance of 32 medical students.[9] Furthermore, Berguer et al. proposed that sex differences may be at least partially attributed to hand size, as certain laparoscopic instruments may not be ergonomically suited for smaller hands.[25] Our study shows that sex does not have a statistically significant correlation with baseline laparoscopic skill in medical students.

There are some limitations to this study. Recruitment was made through convenience sampling of a first-year medical school cohort, resulting in potential selection bias. Secondly, while the intervention group was required to pass all the levels, the amount of time spent and the number of medals earnt on the SimuSurg application were not recorded. Lastly, it is unclear how well smartphone applications translate to laparoscopic performance in the operating theatre. Future research should investigate the effect of smartphone simulators on laparoscopic performance in the operating theatre or compare it to other training modalities such as virtual reality simulators.

Our results suggest that smartphone applications may improve the laparoscopic ability of medical students, especially for the non-dominant hand. These simulators are inexpensive and accessible, and may serve as a useful adjunct to laparoscopic training in surgically inexperienced students and clinicians.

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Conflicts of interest: none.

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Table 1: Results from Wilcoxon signed-rank test comparing first and second testing session scores in control and intervention groups

Activity	**Control group, median score (25th-75th percentile)**			**p-value**	**Intervention group, median score (25th-75th percentile)**			**p-value**
	First session	*Second session*	*Median change*		*First session*	*Second session*	*Median change*	
Beads	380.50 (336.75-482.75)	374.50 (302.00-425.50)	6.00	0.59	446.50 (368.50-645.00)	365.50 (291.00-448.75)	81.00	0.01
Washers	190.00 (119.50-301.00)	142.00 (85.75-232.00)	48.00	0.12	172.50 (124.25-300.75)	134.00 (112.75-163.75)	38.50	0.04
Rope	281.50 (168.75-325.00)	207.00 (144.00-294.50)	74.50	0.06	301.00 (160.50-345.00)	270.00 (138.50-360.00)	31.00	0.31
Total	892.00 (785.00-1018.50)	730.50 (619.00-863.25)	161.50	0.08	954.50 (776.25-1119.00)	772.50 (554.25-935.75)	182.00	0.009

Table 2: Results from Wilcoxon signed-rank test comparing dominant and non-dominant hand scores in control and intervention groups

Session	**Control group, median score (25th-75th percentile)**			**p-value**	**Intervention group, median score (25th-75th percentile)**			**p-value**
	First session	*Second session*	*Median change*		*First session*	*Second session*	*Median change*	
Dominant hand	215.00 (153.75-259.00)	189.00 (124.50-220.50)	26.00	0.32	238.00 (192.00-320.00)	176.00 (130.00-243.50)	62.00	0.08
Non-dominant hand	191.00 (127.50-259.00)	182.00 (141.25-254.25)	9.00	0.98	235.50 (186.50-345.00)	169.00 (136.50-259.25)	66.50	0.008

Table 3: Demographic data of control and intervention groups

Category	**Control group (n=15)**	**Intervention group (n=15)**
Age, mean (SD)	22.29 (4.50)	22.79 (3.49)
Sex, female (%)	8 (53.33)	7 (46.67)
Interest in surgery as a career, yes (%)	8 (53.33)	10 (66.67)
Regular gamer*, yes (%)	8 (53.33)	9 (60.00)

*Defined as playing video games one or more times per week

Figure 1: Overview of participant recruitment

[High resolution figure supplied separately]