The Knee 47 (2024) 129–138

Contents lists available at ScienceDirect

The Knee

journal homepage:

Evaluating the effectiveness of a low fidelity, easily available simulator to teach basic arthroscopy skills to novice learners: A prospective cohort study

Malcolm Scott-Watson [a,*], Chris Thornhill [b], Rahul Bhattacharyya [c], Simon J. Spencer [d]

[a] Glasgow University Medical Student, Wolfson Medical School Building, University Avenue, University of Glasgow, G12 8QQ, UK
[b] ST3 Orthopaedic and Trauma Surgeon, Queen Elizabeth University Hospital, 1345 Govan Road, Govan G51 4TF, Glasgow, UK
[c] Consultant Orthopaedic and Trauma Surgeon, NHS Lanarkshire University Hospitals, UK
[d] Consultant Orthopaedic and Trauma Surgeon, Queen Elizabeth University Hospital, 1345 Govan Road, Govan G51 4TF, Glasgow, UK

ARTICLE INFO

Article history:
Received 15 November 2023
Revised 22 December 2023
Accepted 7 February 2024

Keywords:
Arthroscopy
Orthopaedic Training
Simulation
Student training

ABSTRACT

Background: Arthroscopy proficiency is key to being a competent orthopaedic surgeon and acquiring arthroscopic skills takes years of exposure and diligent practice. However, today's graduating consultants have had considerably less time in operating theatre than their senior colleagues at the same point of their careers.
Objectives: To evaluate whether: (1) Students could improve their arthroscopic technique using a low fidelity arthroscopic training tool (2) students enjoyed the use of the simulator (3) If certain demographics correlate to performance on the simulator.
Methods: Medical students who have no previous training in arthroscopy were included. A combined left- and right-handed timed run with a low-fidelity arthroscopic triangulation simulator was recorded before and after 40-minutes of practice.
Results: 84 participants took part with an average improvement of was 66.8%. Students felt that their arthroscopic skills increased on average by 36.4%. 73 of the 84 participants gave the maximum score of 5 when asked if they enjoyed the session and 74 participants gave the maximum score of 5 as to whether they would be interested in participating in further sessions. Factors such as biological sex, video game play and sports were found to be statistically significant to performance.
Conclusions: This study showed a statistically significant improvement in students' arthroscopic performance with a low-fidelity arthroscopic simulator. Students found the experience useful with the vast majority indicating interest in completing further training sessions to help improve practical surgical skills. Video gamers, sports players and males were found to have a correlation with performance on the simulator.

1. Introduction

Acquiring proficient arthroscopic skills takes years of exposure and diligent practice. Enforced restrictions in training time have resulted in significantly less first-hand exposure to arthroscopy procedures for current surgical trainees when

* Corresponding author.
E-mail addresses: 2297400s@student.gla.ac.uk (M. Scott-Watson), christopher.thornhill2@nhs.scot (C. Thornhill), rahul.bhattacharyya@lanarkshire.scot.nhs.uk (R. Bhattacharyya), simon.spencer@ggc.scot.nhs.uk (S.J. Spencer).

https://doi.org/10.1016/j.knee.2024.02.001
0968-0160/© 2024 The Author(s). Published by Elsevier B.V.

compared to previous times [1]. Therefore, the ability of future surgeons to perform arthroscopy and reach the same level of safety and efficiency as their predecessors has become a potential concern.

A commonly cited reason for reduction in trainee theatre time is the 2009 European Working Time Directives (EWTD) [2] which further limited doctors to a 48-hour working week. It was estimated that the amount of time a surgical trainee could expect to work between Senior House Officer (SHO) and Consultant prior to the EWTD was 30,000 hours, however since the EWTD, this is expected to have dropped down to 6,000 hours [1,3]. Institutions including the General Medical Council (GMC) [4] and Association of Surgeons in Training (ASiT) [5] have argued this could be detrimental to a doctor's training, with surgical specialities "bearing the brunt" of the restriction [6]. The new directives also meant that there was a need to increase the number of junior surgical trainees to satisfy rotas resulting in higher 'competition' for time in theatres and a reduction in overall theatre time during training [7]. As famously said in a book written by Malcolm Gladwell, "it takes 10,000 hours of intensive practice to achieve mastery of complex skills", and with no additional adjuncts, this is what is at risk for the modern surgical trainee [8].

The COVID-19 pandemic has also had a drastic impact on orthopaedic training. One paper [9] found that the number of eLogbook recorded orthopaedic surgeries dropped by 40% when comparing 2019 to 2020. The British Journal of Surgery estimated that over 28 million elective surgeries across the globe had to be cancelled because of the pandemic [10], with orthopaedics being one of the slowest specialties to return to pre-pandemic activity [11]. The Scottish arthroplasty project dataset [12] found that in the 6 months following the resumption of elective services, Scottish hospitals averaged less than 50% of the normal pre-pandemic output [13].

One potential solution to this problem is simulated training, with simulation in orthopaedic training have gained significant popularity due to the reasons stated above. Cadaveric and virtual reality simulation have demonstrated benefits in orthopaedic training [14–16] but are limited by availability and cost. Repeated sustained practice is key to learning skills and therefore, simulation platforms that are easily available to trainees have gained in popularity. Cognitive Task Analysis (CTA) [17–19] training tools in recent years have shown significant benefits in teaching novice trainees basic arthroscopy skills. The low fidelity simulator is a simple and relatively inexpensive device which could be made readily available to trainees to allow repeated practice. It can be an ideal adjunct to the CTA tools in the simulation ladder. A learner can develop their cognitive understanding with the CTA tools and then practice aspects of arthroscopy such as triangulation and visual-spatial skills using a low fidelity simulator. This can help them progress quicker through the learning curve thereby improving the efficiency of operating theatre training time.

The primary aim of this study was to determine if a low fidelity simulator demonstrated a training effect in novice learners.

The secondary aim was to determine if there was a correlation between hobbies and demographics and any possible observed training effect in novice learners.

2. Methods

2.1. Inclusion criteria

Medical students in non-clinical years (years 1–3) from the University of Glasgow were invited to take part in the study. Exclusion criteria included any previous training in arthroscopy or any active participation in an arthroscopic surgery – defined as having scrubbed in during an arthroscopic operation.

2.2. Equipment

The low fidelity simulator (ArthroBox, Arthrex, Naples, FL) is a non-anatomic, low-fidelity triangulation simulator. The aim of the box is the allow trainees to "practice basic arthroscopic skills" especially arthroscopic triangulation [20]. The box is approximately the size of a knee or shoulder joint and contains an arthroscope (with USB attachment), a probe and a task. The arthroscope was plugged into a laptop placed directly behind the simulator (Figures 1 and 2). Students sat whilst completing the task.

2.3. The task

The task comprised guiding a small rubber ring from one side of a triple looped metal frame to the other (Figures 3 and 4). The rules were as shown in Figure 5:

2.4. Background information

A background information sheet was given to participants prior to their session to collect basic demographic details (age, sex assigned at birth, medical school year, hand dominance) and further questions about hobbies such as musical instruments, video gaming and sports.

Figure 1. Demonstrating the setup of the low fidelity simulator with a participant attempting a right-handed attempt.

Figure 2. Demonstrating the setup used with 4 participants attempting their 1st attempts at the task.

- A participant's "hand dominance" was based on the hand they wrote with. Participant were considered mix-handed if they completed different activates with different hands.
- Sports ability was ranked from 1-5 depending on ability (1 = novice, 2 = recreational, 3 = competitive, 4 = county, 5 = national), in a similar manner to a previous study using a low fidelity simulator [21].

Following the session, data was collected to assess subjective student satisfaction using the simulator.

Figure 3. Demonstrating the setup for a Left-handed attempt at the task, the ring will be moved from the left to right with the left hand using the probe.

Figure 4. Demonstrating the setup for a Right-handed attempt at the task, the ring will be moved from the right to the left with the right hand using the probe.

Note: following example is for a "**right-hand attempt**"

- With the ring started on the right, students were told to hold the probe in their right hand and the arthroscope in their left hand. The probe and arthroscope would be placed in the lower right and left ports of the top panel respectively. (Picture 4)
- With both tools located in the box, students were told to start a timer and begin moving the rubber ring from the right side of the metal frame to the left. Once completed, the time would be recorded, and the same procedure repeated with the left hand.
- The probe could be moved to different ports during the attempt with 5-seconds added to their time for every port change.

Figure 5. Description of task carried out by students.

2.5. Session structure

Sessions were run at the University of Glasgow. An instructor demonstrated the task to all participants prior to their attempts.

Participants record their first attempt at the task with both their left and right hand before being given 40 minutes to practice. Following the practice time, all students were timed completing their "final attempt".

2.6. Statistical analysis

All the data collected was recorded and analysed using Microsoft Excel version 16.76.

A two tailed Mann Whitney U test was used for comparing different populations.

Correlation values were calculated using Spearman's rank. A significance level of $P \leq 0.05$ was used for all tests.

3. Results

A total of 84 participants (55 females, 27 males, 2 who identified as "other") took part in the study. The average age was 21.2 years (IQR: 19.3–22.5).

The average time to complete the first and final attempts was 305.0 seconds (SD: 237.0) and 101.3 seconds (SD: 85.7) respectively, giving an average improvement of 66.8% ($p = <0.0001$).

3.1. Hobbies & demographics

Males were marginally faster (26.5% 245.7 vs 334.5, $P = 0.280$) than females during their first attempt and 41.2% faster (70.1 vs 119.2, $P = 0.018$) during their final attempts.

There was no correlation between age, medical school year, musical instrument participation/ability and the speed at which the task could be performed. Similarly, the number of instruments a participant could play made no statistical difference to the outcome – Table 1.

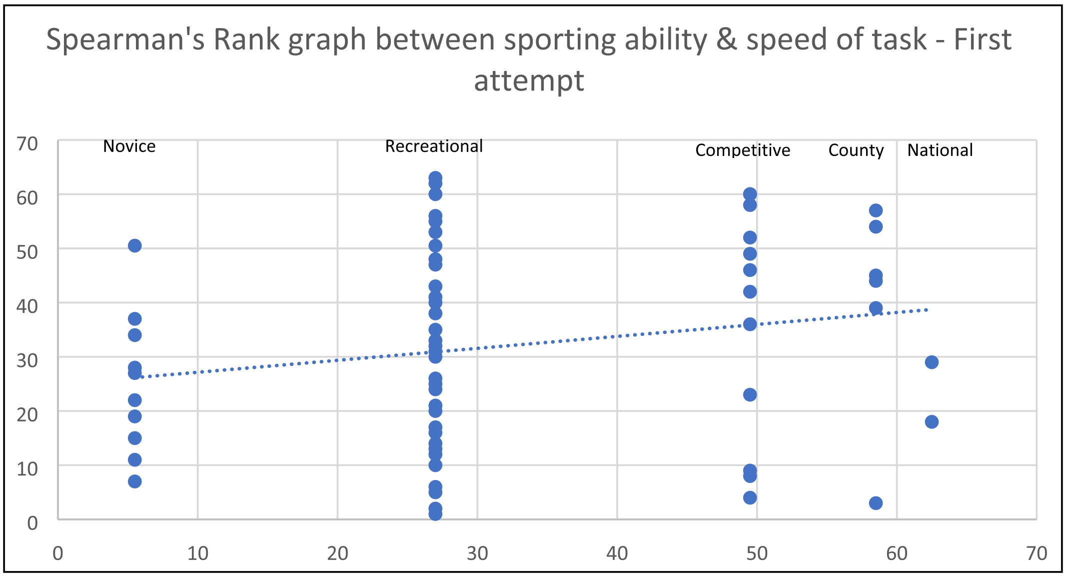
There was no difference between those who play sports and those who do not. However, within those who played sports there was a weak correlation between the level at which the sport was played and their ability on the simulator during their first attempt ($r = 0.203$, $p = 0.032$ – Graph 1) and a moderate correlation during their final attempt ($r = 0.422$, $p < 0.0001$ – Graph 2).

People who described themselves as having mix-hand dominance were 42.8% faster (180.9 vs 316.3, $P = 0.043$) than non-mix-hand dominant participants during their first attempts. However, this was reduced to 21.5% (82.3 vs 104.8, $P = 0.951$) in their final attempts. As with mix-hand dominant participants, those interested in surgery as a future career were found to be 35.0% (250.4 vs 385.4, $P = 0.038$) faster during their first attempt but were not significantly faster during their final attempt (10.2%, 96.9 vs 107.9, $P = 0.373$). On average people were 36.1% & 33.0% slower (129.2 vs 175.9, $p < 0.001$ & 44.2 vs 58.7$p = 0.008$) with their non-dominant hand on their first and final attempts respectively.

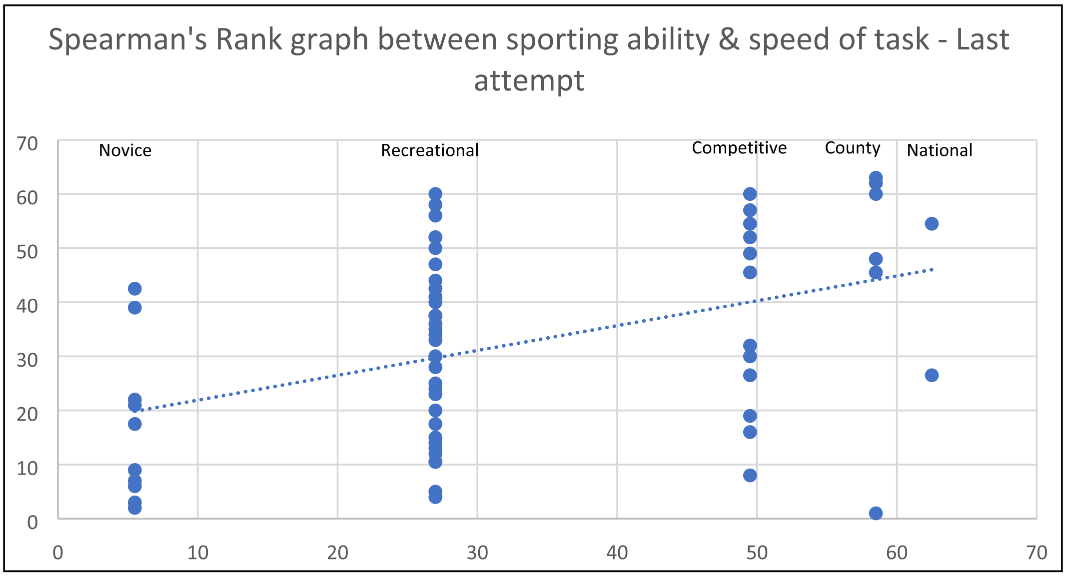
Participants with videogame playing experience were 37.8% (227.6 vs 366.0, $P = 0.051$) faster than their counterparts during their first attempts and 33.6% (84.1 vs 117.7, $P = 0.048$) faster during their final attempts.

3.2. Participant interest

When asked if students enjoyed using the low fidelity simulator, 73 out of the 84 participants gave the maximum score of 5. 74 of the 84 participants gave a score of 5 when asked if they would be interested in having further sessions to improve their arthroscopic technique. On average, participants also believed the session helped improve their hand-eye coordination (average score = 4.49).



Graph 1. X-axis depicts the Spearman's rank for each of the 5 levels of sports ability (Novice, Recreational, Competitive, County National) Y-axis depicts the Spearman's rank for each participant's time on the low fidelity simulator during their first attempt.



Graph 2. X-axis depicts the Spearman's rank for each of the 5 levels of sports ability (Novice, Recreational, Competitive, County National). Y-axis depicts the Spearman's rank for each participant's time on the low fidelity simulator during their first attempt.

Time taken to complete the task based on demographic.
Tables 1 and 2.

4. Discussion

4.1. Training effect

Participants significantly improved their time to complete the simulator task after the given practice period. This demonstrates a training effect of the low fidelity simulator over a short space of time for the sampled cohort, and this is supported by results seen in other studies [21–23]. Vaghela et al. [22] compared participants' improvement in completing tasks on a low fidelity simulator after a training period, with the test group (n = 10) using the simulator at home for a month, versus

Table 1
Timed results for different demographics (Significant results in bold). r-values are for Spearman's rank correlation (with corresponding p-values), solitary p-values are for two-tailed Mann-Whitney U tests.

		First attempt		Final attempt	
		Mean, sec (Standard deviation)	P-value /r-value	Mean, sec(Standard deviation)	P-value/r-value
Total average (n = 84)		305.0 (237.0)		101.3 (85.7)	
Gender	Male (n = 27)	245.7 (138.0)	P = 0.280	70.1 (28.3)	**P = 0.018**
	Female (n = 55)	334.5 (272.9)		119.2 (111.3)	
Medical School Year	1 (n = 19)	311.2 (292.7)	r = -0.060	128.4 (124.5)	r = -0.024
	2 (n = 54)	318.2 (235.1)	(P = 0.294)	113.5 (78.3)	(P = 0.414)
	3 (n = 11)	244.6 (164.8)		73.27 (40.2)	
	4 (n = 2)	354.0 (45.3)		118.0 (12.7)	
Age	As age went up (n = 84)	r = -0.109 (p = 0.162)		r = -0.038 (0.364)	
Arthroscopy	Seen (n = 10)	320.0 (249.1)	P = 0.904	140.7 (71.2)	P = 0.757
	Never Seen (n = 74)	303.0 (237.0)		96.0 (157.0)	
Hand dominance	Left (n = 10)	272.7 (194.6)	P = 0.569	93.6 (49.3)	P = 0.803
	Right (n = 74)	309.4 (243.0)		104.2 (98.7)	
	Mix-Handed (n = 7)	180.9 (58.0)	**P = 0.043**	82.3 (28.7)	P = 0.951
	Not Mix-Handed (n = 77)	316.3 (244.0)		104.8 (97.7)	
	Dominant hand	129.2(149.7)	**P < 0.001**	44.2 (60.3)	**P = 0.008**
	Non-dominant hand	175.9 (142.2)		58.7 (41.7)	
Interest in Surgery	Interested (n = 50)	250.4 (151.5)	**P = 0.075**	96.9 (92.1)	P = 0.373
	Not interested (34)	385.4 (309.8)		107.9 (76.0)	
Sports	Play Sports (n = 63)	302.1 (229.3)	P = 0.711	103.7 (98.6)	P = 0.689
	Don't play (n = 21)	314.0 (264.6)		100.7 (81.1)	
	(1) Novice (n = 10)	371.5 (126.5)	**r = 0.203**	169.0 (133.8)	**r = 0.422**
	(2) Recreational (n = 33)	350.0 (255.2)	**(p = 0.032)**	88.8 (38.1)	**(p < 0.0001)**
	(3) Competitive (n = 12)	341.8 (214.9)		75.8 (34.6)	
	(4) County (n = 6)	183.2 (315.2)		144.3 (248.5)	
	(5) National (n = 2)	308.3 (64.3)		66.5 (29.0)	
Video Games	Have Played (n = 37)	227.6 (122.1)	P = 0.051	84.1 (80.7)	**P = 0.048**
	Never Played (n = 47)	366.0 (289.9)		117.7 (103.1)	
	Still Play (n = 24)	209.3 (88.3)	P = 0.197	83.0 (92.2)	P = 0.150
	Don't still play (n = 13)	261.5 (158.0)		86.0 (57.9)	
Musical Instruments	Have played (65)	292.6 (217.7)	P = 0.373	98.0 (87.2)	P = 0.497
	Never played (19)	347.6 (296.6)		119.5 (115.5)	
	Still Play (n = 26)	296.3 (258.2)	P = 0.363	108.6 (119.1)	P = 0.363
	Don't still play (n = 39)	290.2 (189.6)		91.0 (57.9)	
	0 Instruments (n = 19)	347.6 (296.6)	r = 0.018	119.5 (115.5)	r = 0.033
	1 Instrument (n = 43)	294.3 (244.8)	(P = 0.434)	99.0 (99.4)	(P = 0.383)
	2 Instruments (n = 18)	286.4 (168.6)		99.8 (61.4)	
	3 + Instruments (n = 4)	302.0 (103.4)		79.8 (45.0)	
	Grade 0 (n = 2)	179.5 (61.5)	r = 0.129	49.0 (17.0)	r = 0.054
	Grade 2 (n = 1)	582.0 (NA)	(P = 0.199)	138.0 (NA)	(P = 0.363)
	Grade 3 (n = 4)	309.5 (253.8)		101.3 (74.4)	
	Grade 4 (n = 4)	416.5 (339.8)		217.0 (290.0)	
	Grade 5 (n = 7)	234.7 (170.0)		90.0 (73.4)	
	Grade 6 (n = 4)	248.3 (140.4)		68.8 (28.7)	
	Grade 7 (n = 7)	346.6 (212.1)		111.4 (66.8)	
	Grade 8 (n = 12)	319.2 (300.3)		86.6 (37.9)	
	Diploma (n = 4)	158.0 (60.2)		56.25 (21.0)	

Table 2
Results to questions asked before and after the session. All answers are scored out of 5, with 1 being "very poor" & 5 being "very good".

Questions asked before and after the session (out of 5):	**Before:**	**After:**	**Difference**
Q1: How would you currently rate your understanding/knowledge of arthroscopic surgery?	1.92	3.74	95%
Q2: How would you rate your arthroscopic ability?	1.62	3.39	110%
Q3: How confident would you be in assisting in arthroscopic surgery?	1.70	3.07	80%
Questions asked after the session (out of 5):			
Q4: Did you enjoy using the simulator?	4.83		
Q5: Did you find the session useful for improving your hand-eye coordination?	4.86		
Q6: If further sessions were run to improve your arthroscopic skills, would you be keen on participating?	4.49		

a control group (n = 10). The scores measured by the Arthroscopic Surgical Skills Evaluation Tool (ASSET), which is a video-based assessment tool using 8 domains of arthroscopic skill to give a score of global arthroscopic ability, were significantly improved in the test group, and not improved in the control group, further demonstrating the training effect of the simulator. Redondo et al. [23] took 28 medical students and allowed half to practise for 3 x 30-minute sessions a week for 4 weeks. They then compared improvement of pre-practise and post-practise ASSET scores with control participants, and again showed a statistically significant difference in favour of the test group. Similar results were shown by Bouaicha et al. [24] when comparing participants who had undergone 3 x 60-minute simulator sessions with controls, and then assessed on a high-fidelity simulator. Various performance measures were analysed, and a significant difference in improvement was seen between test and control groups.

In terms of application of simulator training, it has been shown that practise on a simulator has transferable benefit to the operating theatre. Howell et al. [25] randomised orthopaedic trainees to a fixed-protocol simulator group or a control group. They then were assessed by a blinded knee consultant whilst performing a diagnostic knee arthroscopy in theatre under supervision. The simulator group performed significantly better in this study, showing utility of this training modality.

Other training modalities exist to aid arthroscopic training. Bhattacharyya et al. [17] created a Cognitive Task Analysis (CTA) tool for diagnostic knee arthroscopy. This comprised of written descriptions as well as video recordings of the procedure, separated into phases. This tool, known as the Imperial Knee Arthroscopy Cognitive Task Analysis (IKACTA) Tool, was then shown to significantly improve performance in tasks on a high-fidelity simulator when compared to control participants [19], showing CTA as a potentially useful training tool for knee arthroscopy that has the advantage of being easily accessible and inexpensive when compared to physical simulators.

4.2. Factors predicting performance

There was a statistically significant difference between male and female performances after the practice period. The same was seen in videogamers vs non-videogamers which may help explain the male/female difference since 85% of males played video games in comparison to only 24% of females. Moreover, in those who played videogames, males played on average 38% more than their female colleagues. Previous studies have shown mixed results when discussing the correlation between video game use and surgical skill abilities [21,26–29]. However, our study has a larger sample size than previous studies (n = 84 compared with n = 49 [21], n = 43 [26], n = 30 [27], n = 20 [28]), increasing the validity of the relationship between the two groups. Secondly, our study measured participants' ability to perform the task using both with their right and left hand which gives a more comprehensive overview of each participant's overall visuospatial ability. Gamers get a chance to train their non-dominant hand to help improve visuospatial coordination, something non-videogames may not be doing on a regular basis. The authors believe that ability to use both hands effectively is advantageous in arthroscopic surgery.

There have been many conflicting studies conducted on the effect of sports participation on the ability to develop surgical techniques [21,26–28]. We found a weak/moderate but statistically significant correlation between a participant's level of sport and their first/final attempts at the task, with those performing sports at a higher level achieving a faster time at the simulation. This is in accordance with the theory that active participation in sports increases hand-eye coordination and proprioception - both important aspects in arthroscopy.

4.3. Student survey

The study shows that even in a short period of time students felt that their knowledge and ability in arthroscopy both drastically increased. Participants were in their non-clinical years of medical school and therefore had very little clinical experience. Added to the impact of COVID-19, students enjoyed the ability to get in-person, hands-on experience within the medical field.

This study shows the enthusiasm students have for practical and interactive learning methods. The authors also believe that low-fidelity surgical tools, could be a successful method of getting medical students interested in a surgical career. More frequent sessions involving active learning could improve the overall student satisfaction of medical school, decreasing student anxiety & depression, both of which are common among medical students [29–31] by providing a more interactive and sociable learning experience.

4.4. Limitations

The authors understand that this is a low fidelity simulator of arthroscopic surgery and therefore proficiency in the task set is not to be used as an indicator of arthroscopic ability, but only as an ability of arthroscopic triangulation. More realistic simulators currently exist, such as VR simulators which includes anatomical aspects of arthroscopic surgery. However, even with these more advanced simulators the current level of evidence of their efficacy remains low [32]. Although this study had a greater sample size than many comparable studies, relationships between different groups of individuals would be more reliable with a larger cohort. The study did not take interim measurements of performance during the practice time; therefore, the learning curve cannot be assessed. This would have allowed it to be seen if participants had hit a plateau with their ability or whether they were still improving, hence a further study with more regular monitoring, longer practice time and multiple sessions, would be useful in understanding the pattern of improvement between different participants/groups.

5. Conclusion

This study established that there was a significant improvement in performance of arthroscopic triangulation even after a short period of practice, demonstrating a training effect. It also showed that students enjoyed the practical experience with surgical techniques and that this form of teaching could help introduce students to a surgical career. The study highlighted statistically significant differences between factors including: (1) being male; (2) video game experience; and (3) higher levels of sports participation and the ability of participants to complete a task testing arthroscopic triangulation in the shortest time.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Malcolm Scott-Watson: Conceptualization, Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Project administration. **Chris Thornhill:** Writing – original draft, Writing – review & editing, Conceptualization, Project administration. **Rahul Bhattacharyya:** Writing – original draft, Writing – review & editing, Formal analysis, Conceptualization, Supervision. **Simon J. Spencer:** Conceptualization, Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Thomas RL, Karanjia N. Comparison of SHO surgical logbooks a generation apart. The Bulletin of the Royal College of Surgeons of England 2009;91(10):356–9.
[2] Working Conditions, European Working Time Directive - Employment, Social Affairs & Inclusion - European Commission. Available at: https://ec.europa.eu/social/main.jsp?catId=706&langId=en&intPageId=205 (Accessed: 14 November 2023).
[3] Chikwe J, de Souza AC, Pepper JR. No time to train the surgeons. BMJ 2004;328(7437):418–9.
[4] The impact of the implementation of the European Working Time ... - gmc (2011) General Medical Countcil. Available at: https://www.gmc-uk.org/-/media/documents/the-impact-of-the-implementation-of-the-european-working-time-directive–ewtd–42536543.pdf (Accessed: 03 October 2023).
[5] Asit Abstracts. Annals of The Royal College of Surgeons of England. 2007;89(4):7–11. Available from: https://publishing.rcseng.ac.uk/doi/pdf/10.1308/147363513X13588739440690.
[6] Horvath KD, Pellegrini CA. Commentary on: "impact of the european working time directive (EWTD) on the operative experience of surgical residents". Surgery 2015;157(4):642–4.
[7] Toll EC, Davis CR. More trainees and less operative exposure: A quantitative analysis of training opportunities for junior surgical trainees. The Bulletin of the Royal College of Surgeons of England 2010;92(5):170–3.
[8] Gladwell M. Outliers: The story of success. New York: Back Bay Books, Little, Brown and Company; 2019.
[9] Bates T, Cecil E, Greene I. The effect of the EWTD on training in general surgery: An Analysis of Electronic Logbook Records. The Bulletin of the Royal College of Surgeons of England 2007;89(3):106–9.
[10] Elective surgery cancellations due to the COVID-19 pandemic: Global predictive modelling to inform Surgical Recovery Plans. British Journal of Surgery. 2020.
[11] Boa. Progress on restarting elective orthopaedic surgery [Internet]. British Orthopaedic Association. 2020 [cited 2022Nov10]. Available from: https://www.boa.ac.uk/resources/progress-on-restarting-elective-orthopaedic-surgery.html.
[12] The Scottish Arthroplasty Project [Internet]. NHS choices. NHS; 2022 [cited 2022Nov10]. Available from: https://www.arthro.scot.nhs.uk/.
[13] Yapp LZ, Clarke JV, Moran M, Simpson AH, Scott CE. National Operating Volume for primary hip and knee arthroplasty in the COVID-19 ERA: A study utilizing the Scottish arthroplasty project dataset. Bone & Joint Open 2021;2(3):203–10.
[14] Logishetty K, Rudran B, Cobb JP. Virtual reality training improves trainee performance in total hip arthroplasty: A randomized controlled trial. The Bone & Joint Journal 2019;101-B(12):1585–92. doi: https://doi.org/10.1302/0301-620x.101b12.bjj-2019-0643.r1.
[15] James HK et al. How does cadaveric simulation influence learning in orthopedic residents? J Surg Educ 2020;77(3):671–82. doi: https://doi.org/10.1016/j.jsurg.2019.12.006.
[16] James HK, Fawdington RA. 'Freestyle deliberate practice cadaveric hand surgery simulation training for orthopedic residents: Cohort study'. JMIR Med Educ 2022;8(2). doi: https://doi.org/10.2196/34791.
[17] Bhattacharyya R et al. 'Knee arthroscopy'. JBJS Essential Surgical Techniques 2018;8(4). doi: https://doi.org/10.2106/jbjs.st.18.00017.
[18] Karamchandani U et al. Training surgeons to perform arthroscopic all-inside meniscal repair: A randomized controlled trial evaluating the effectiveness of a novel Cognitive Task Analysis Teaching Tool, Imperial College London/University College London Meniscus Repair Cognitive Task Analysis (IUMERCTA). Am J Sports Med 2021;49(9):2341–50. doi: https://doi.org/10.1177/03635465211021652.
[19] Bhattacharyya R et al. Knee arthroscopy simulation. J Bone Joint Surg 2017;99(19). doi: https://doi.org/10.2106/jbjs.17.00190.
[20] ArthroBox® [Internet]. Arthrex. [cited 2022Nov10]. Available from: https://www.arthrex.com/imaging-resection/arthrobox.
[21] Richey BP, Deal MJ, Baker A, Mason EM, Zeini IM, Osbahr DC, et al. Predictors of performance on the Arthrobox arthroscopy simulator for medical students. Arthroscopy, Sports Medicine, and Rehabilitation 2020;2(6).
[22] Vaghela K, Lee J, Heidari N, Akhtar K. Training effect of a portable, low-cost 'take home' arthroscopic skills simulator. BMJ Simulation & Technology Enhanced Learning 2016 Nov;1(2):A16.
[23] Redondo ML et al. The effect of triangulation simulator training on arthroscopy skills: A prospective randomized controlled trial. Arthroscopy, Sports Medicine, and Rehabilitation 2020;2(2). doi: https://doi.org/10.1016/j.asmr.2019.10.010.

[24] Bouaicha S et al. Three Days of training with a low-fidelity arthroscopy triangulation simulator box improves task performance in a virtual reality high-fidelity virtual knee arthroscopy simulator. Knee Surg Sports Traumatol Arthrosc 2019;28(3):862–8. doi: https://doi.org/10.1007/s00167-019-05526-y.
[25] Howells NR et al. Transferring simulated arthroscopic skills to the Operating Theatre. The Journal of Bone and Joint Surgery British 2008;90-B (4):494–9. doi: https://doi.org/10.1302/0301-620x.90b4.20414.
[26] Cychosz CC, Tofte JN, Johnson A. Factors impacting initial arthroscopy performance and skill progression in novice trainees Available at:. The Iowa Orthopedic Journal 2019;39:7–13. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6604553/.
[27] Shee K, Ghali FM, Hyams ES. Practice makes perfect: Correlations between prior experience in high-level athletics and robotic surgical performance do not persist after task repetition. J Surg Educ 2017;74(4):630–7.
[28] Rahm S, Wieser K, Wicki I, Holenstein L, Fucentese SF, Gerber C. Performance of medical students on a virtual reality simulator for knee arthroscopy: An analysis of learning curves and predictors of performance. BMC Surg 2016;16(1).
[29] Mirza AA, Baig M, Beyari GM, Halawani MA, Mirza AA. Depression and anxiety among medical students: A brief overview. Adv Med Educ Pract 2021;12:393–8.
[30] Pokhrel NB, Khadayat R, Tulachan P. Depression, anxiety, and burnout among medical students and residents of a medical school in Nepal: A cross-sectional study. 2020;
[31] Honney K, Buszewicz M, Coppola W, Griffin M. Comparison of levels of depression in medical and non-medical students. Clin Teach 2010;7(3):180–4.
[32] Morgan M et al. Current status of simulation-based training tools in orthopedic surgery: A systematic review. J Surg Educ 2017;74(4):698–716. doi: https://doi.org/10.1016/j.jsurg.2017.01.005.