

Virtual Reality Simulator Use Stimulates Medical Students' Interest in Orthopaedic Surgery



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Purpose: To investigate whether the use of a VR arthroscopic simulator can influence medical students' attitudes toward a career in orthopaedic surgery. **Methods:** Twenty-five medical students completed seven unsupervised sessions on a VR hip-arthroscopic simulator. All participants completed a pre-simulator and post-simulator pseudo-anonymized questionnaire consisting of 10 questions: six 10-point Likert scale questions addressing their interest in orthopaedics, surgery, and arthroscopy; and four 5-point Likert scale questions addressing their attitudes toward simulation. Prepaired and postpaired datasets were analyzed using Wilcoxon signed rank test. **Results:** Interest in both orthopaedics and surgery was found to increase after simulator use (orthopaedics: $5.3 \pm .3$ to $8.4 \pm .2$, $P = .0001$; surgery: $5.8 \pm .3$ to $9.0 \pm .2$; $P = .0001$). It was also found that simulator use increased participants' interest in arthroscopy ($5.4 \pm .3$ to $8.0 \pm .3$; $P = .0001$) and hip-arthroscopy ($5.0 \pm .3$ to $7.6 \pm .3$; $P = .0001$). Participants reported they were more likely to attend endoscopic and arthroscopic surgical lists after simulator use (endoscopic: $6.9 \pm .3$ to $8.4 \pm .2$; $P = .0003$; arthroscopic: $5.9 \pm .3$ to $8.4 \pm .2$; $P = .0001$). After using the simulator, participants felt more strongly that VR simulation is a valuable training modality ($P = .0025$), that simulation should be a mandatory part of orthopaedics and surgical training ($P = .0001$ and $P = .0001$), and that access to VR simulators improves the quality of surgical training ($P = .0024$). **Conclusions:** These results demonstrate that exposure to VR arthroscopic simulation increased medical students' interest in orthopaedics, surgery, and arthroscopy, without the need for direct supervision. Following VR simulator use, students reported they were more likely to engage with training opportunities, including arthroscopic and endoscopic surgery. **Clinical Relevance:** Understanding factors that stimulate interest in orthopaedic surgery may help programs attract the broadest pool of potential trainees.

Introduction

Application rates to orthopaedic training programs have significantly declined in recent years in the United Kingdom, with surveys noting a marked decline in interest in orthopaedic surgery among medical

students.¹⁻³ Although the reasons for this decline are multifactorial, survey data have revealed that students perceive the insufficient practical exposure in training to be a direct deterrent from pursuing a career in surgery and orthopaedics.⁴⁻⁶ These reductions in trainee operating time, combined with increasing evidence of worse outcomes when orthopaedic procedures are performed by inexperienced surgeons, have led to increasing investigation into virtual reality (VR) simulation as a potential means of additional training.⁷ Demonstration of "real-world" improvement in operative performance and safety following VR simulator training has led authors to suggest that simulation may play a substantial role in the future of orthopaedic surgical training.^{7,8}

Although previous studies have highlighted the importance of early exposure to interactive practical skills sessions in fostering an interest in surgical specialties, these have primarily focused on traditional means of simulation involving animal tissues.^{2,9,10} With the potential advent of VR simulator-based skill

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Table 1. Summary of Participant Demographics

Parameter	Value
Mean age, years (means \pm SD)	21.7 \pm 1.8
Gender (Male:Female)	19:6
Year of Medical School Study (% of Participants)	
Third	12%
Fourth	48%
Fifth	40%
Arthroscopy Experience (means \pm SD)	
Number of times using an arthroscope (simulated or real)	.3 \pm .7
Number of times using a hip arthroscope (simulated or real)	0 \pm 0

acquisition in orthopaedic training programs, it is unclear how exposure to these training methods will impact students' attitudes to a career in orthopaedics.¹¹ Additionally, no previous studies have assessed how medical students perceive the utility of VR simulation, or their attitudes to its potential future implementation in training curricula, an important consideration if trainees are to engage effectively with these training methods.

The purpose of this study, therefore, was to investigate whether use of a VR arthroscopic simulator can influence medical students' attitudes toward a career in orthopaedic surgery. We hypothesize that virtual reality simulator use will increase medical students' interest in orthopaedics and that students will consider VR to be an effective training modality.

Methods

Participants

Twenty-five medical students were voluntarily recruited for this study. Recruitment took place in January and February 2017. Students were recruited by advertising through the medical school mailing list. In order to be included in this study, volunteers must have been a medical student at the institution where the study was conducted. There were no exclusion criteria for participation. No remuneration was provided to the students for participation. Basic demographic information, including gender, age, and year of study was collected (Table 1). Additionally, any experience witnessing arthroscopy (hip and other joint) or using an arthroscope (hip and other joint, and in real-life and simulated) was documented.

Pre-simulator Questionnaire

All participants completed an initial questionnaire consisting of 10 questions regarding their attitudes to a surgical career and their attitudes to simulation training. As we were unable to find a pre-existing validated questionnaire to assess student attitudes toward a surgical career and virtual reality simulation,

the questionnaire used was designed by the authors for use in this study. To allow comparison of pre-simulator and post-simulator questionnaire responses, individuals were a randomly generated identification number (five-digit code). The authors had no method of identifying the participant from their study number. The questionnaire consisted of six questions addressing the students' interest in orthopaedics, surgery, and arthroscopy. A further four questions addressed their opinions regarding the value of simulator training and its potential implementation in training curricula. The six questions addressing the students' attitudes to surgery consisted of a 10-point Likert scale, in which the students could rank their interest. The four questions addressing simulation consisted of a statement stem and a five-point Likert Scale with responses ranking between "1 - Strong Yes" and "5 - Strongly No". A five-point Likert scale was used for this part of the questionnaire, as it has been suggested to increase response rates with no impact on accuracy or reliability when assessing individuals' opinions.¹²

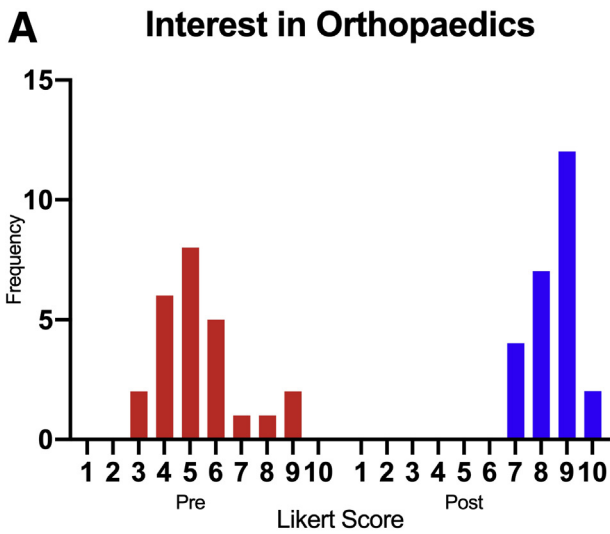
Simulator

The previously validated Symbionix ArthroMentorVR simulator (3D Systems, Littleton, CO) was used for this study.¹³ This simulator consists of a computer and monitor, a mannequin, and two haptic feedback devices capable of providing tactile feedback to a pair of instruments via connecting motors. The mannequin has four predefined 5-mm arthroscopy portals at the modified anterior, anterior, anterolateral, and posterolateral sites. The images of the virtual joint and probe were displayed on the monitor in response to the movements of the operator.

Arthroscopy Simulator Protocol

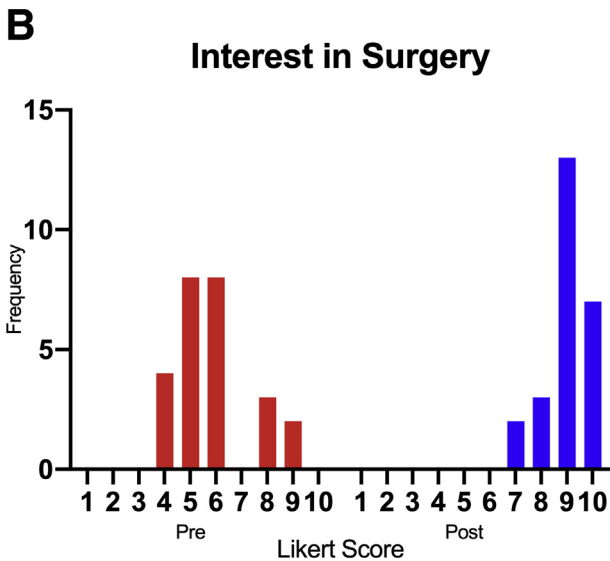
Upon completing the pre-simulator questionnaire, the participants received an identical standardized introduction by the same individual. In this, participants were shown a demonstration of the full diagnostic examination of the hip joint on the simulator. Following this, each participant was given a familiarization period of exactly 3 minutes, in which they could examine the hip joint from all three portals.

Each participant then completed 7 identical independent sessions with the simulator over the course of 7 weeks, with 1 session every 7 days. All students completed these sessions across the same 7-week period. Each session involved locating a series of 12 consecutive targets within the hip joint using an arthroscope. The name of each target was displayed to the participant on screen, and the order in which the targets appeared was identical for each participant. Participants were required to place each target in the center of the monitor for 3 seconds before the name of



Data Analysis

The questionnaire responses were collated, and numerical responses were analyzed using FigurePad (Prism 7; GraphPad Software, Inc., La Jolla, CA) software. Prepaired and postpaired data sets, were analyzed using Wilcoxon signed rank test. Responses from male and female participants were compared using Kruskal-Wallis with Dunn’s multiple-comparison test. *P* values less than .05 were considered significant. Power analysis for a Wilcoxon signed-rank test was conducted in G*Power (G*Power Version 3.1.7, Universität Kiel, Kiel, Germany) to determine a sufficient sample size using an α of .05, a power of .80, a large effect size (Cohen’s $d_z = .78$), and one tail. Cohen’s d_z was calculated using data from a previous study assessing self-reported interest in a career in cardiothoracic surgery before and after use of animal tissue based and computer-based



A Interest in Arthroscopy (Any Joint)

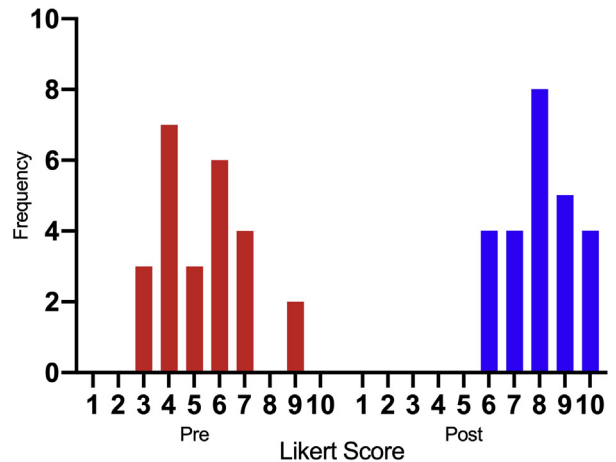


Fig 1. Pre-simulation and post-simulation Likert scores (out of 10) for interest in pursuing a career in orthopaedics (A) and surgery (B).

B Interest in Hip Arthroscopy

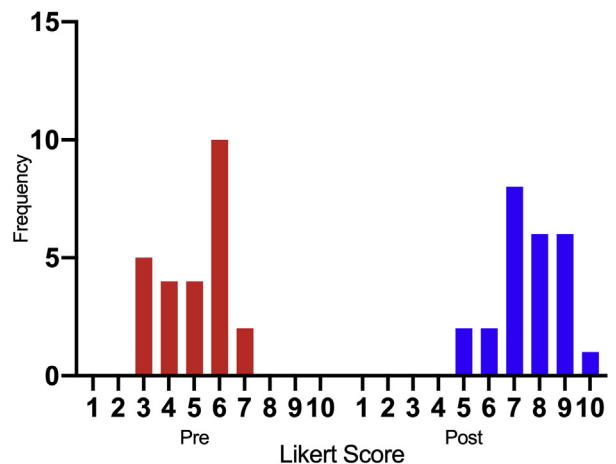


Fig 2. Pre-simulation and post-simulation Likert scores (out of 10) for interest in arthroscopy (any joint) (A) and hip arthroscopy (B).

the next target in the examination sequence was displayed to them on screen. All participants completed all seven sessions.

Following each session, students were given feedback from the simulator regarding their performance. These were calculated using predefined metrics measured by the simulator and included time taken, number of collisions with bone and soft-tissue, and camera steadiness.

Post-simulator Questionnaire

Upon completion of the 7 simulator sessions, the 25 participants then all completed another pseudo-anonymized questionnaire, consisting of the same questions as the pre-simulator questionnaire.

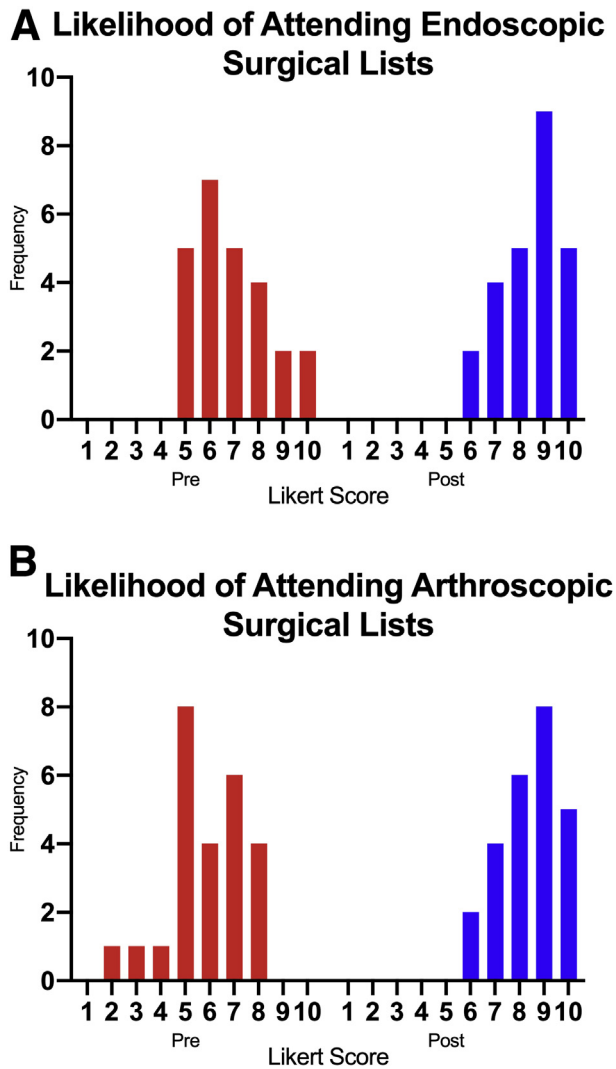


Fig 3. Pre-simulation and post-simulation Likert scores (out of 10) for interest in attending endoscopic (A) and arthroscopic (B) learning opportunities.

simulators.¹⁰ On the basis of the aforementioned assumptions, the desired sample size was 12. Data-collected results are presented as means \pm SE with confidence intervals.

Ethical Approval

As per the National Health Service (NHS) Health Research Authority's guidance, this study did not require approval from an NHS Research Ethics Committee.¹⁴ This study was conducted in agreement with the ethical standards of the University of Cambridge, the NHS Research Ethics Committee, and the 1964 Helsinki declaration.

Results

Interest in Surgery and Arthroscopy

Interest in both orthopaedics and surgery was increased after use of the VR simulator, with the

average interest in orthopaedics increasing from $5.3 \pm .3$ (4.7-5.9) to $8.4 \pm .2$ (8.1-8.8) ($P = .0001$) and the average interest in surgery increasing from $5.8 \pm .3$ (5.2-6.5) to $9.0 \pm .2$ (8.6-9.4) ($P = .0001$) (Fig 1, A and B). It was also found that VR simulator use increased participants' interest in arthroscopy ($5.4 \pm .3$ [4.7-6.0] to $8.0 \pm .3$ [7.5-8.6]; $P = .0001$) and their interest in hip arthroscopy ($5.0 \pm .3$ [4.5-5.5] to $7.6 \pm .3$ [7.0-8.1]; $P = .0001$) (Fig 2, A and B). Participants reported they were more likely to attend endoscopic surgical lists ($6.9 \pm .3$ [6.3-7.5] to $8.4 \pm .2$ [7.9-8.9]; $P = .0003$) and arthroscopic surgical lists ($5.9 \pm .3$ [5.2-6.5] to $8.4 \pm .2$ [7.9-8.9]; $P = .0001$) after simulator use (Fig 3, A and B). Comparison of responses from male and female students for each question revealed no significant differences (interest in orthopaedics pre-simulator: $P = .2155$; interest in surgery pre-simulator: $.7021$; all other questions: $P > .9999$).

Opinions Regarding Simulation Training

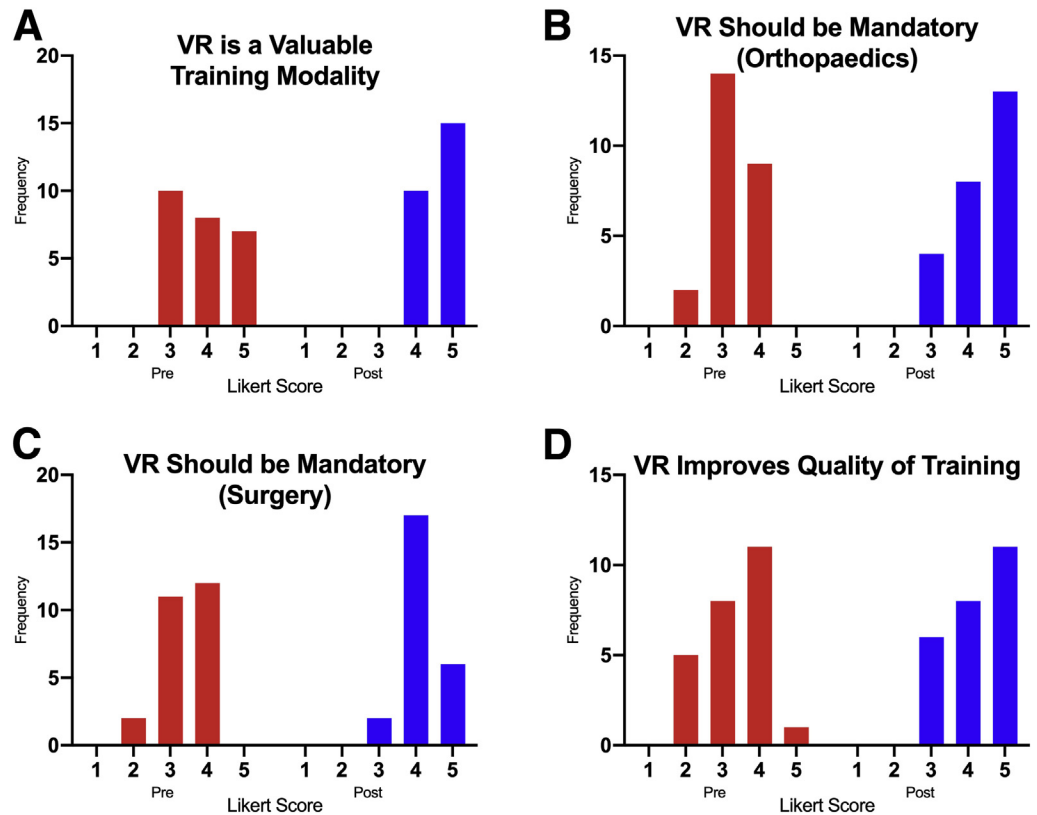
After using the VR arthroscopic surgical simulator, participants felt more strongly that VR simulation (not limited to the simulator used in this study) is a valuable training modality ($3.9 \pm .2$ [3.5-4.2] to $4.6 \pm .1$ [4.3-4.8] out of 5; $P = .0025$) and that VR simulation should be a mandatory part of orthopaedic surgical training ($3.3 \pm .1$ [3.0-3.5] to $4.4 \pm .2$ [4.0-5.0] out of 5; $P = .0001$) and surgical training (any specialty) ($3.4 \pm .1$ [3.1-3.7] to $4.2 \pm .1$ [3.9-4.4] out of 5; $P = .0001$) (Fig 4, A-C). It was also found that participants felt more strongly that access to VR simulators improves the quality of surgical training after using the VR simulator ($3.3 \pm .2$ [3.0-3.7] to $4.2 \pm .2$ [3.9-4.5] out of 5; $P = .0024$) (Fig 4D).

Discussion

The results of this study show that exposure to VR arthroscopic simulation increased medical students' interest in orthopaedics, surgery and arthroscopy. It was also found to positively influence their potential future engagement with surgical opportunities and their opinions regarding the utility of VR simulation training. This study demonstrates a novel and less labor-intensive means of stimulating interest in this specialty than traditional didactic and workshop-based methods.

Previous studies assessing potential means of stimulating interest in orthopaedics and other surgical specialties among medical students have demonstrated that practical and interactive experiences during medical school effectively stimulate interest in pursuing a future surgical career.^{2,9,15} These studies have highlighted the importance of positive interaction with surgical professionals: this can be teaching-based aimed at increasing clinical or career-based knowledge, take the form of interactive practical skills sessions, or via

Fig 4. Pre-simulation and post-simulation Likert scores regarding students' opinions of virtual reality (VR) simulation in surgical training (1, strong yes; 5, strong no). (A) Do you think VR simulation is a valuable training modality? (B) Do you think VR simulation should form a mandatory part of orthopaedic surgical training? (C) Do you think VR simulation should form a mandatory part of surgical training (any specialty)? (D) Do you think the inclusion of VR simulation improves the quality of surgical training?



mentorship relationships between surgeons and students. A recent study in Brazil demonstrated the beneficial impact of societies tasked with increasing knowledge of trauma surgery, providing hands-on operating experience, and organizing apprenticeship opportunities.¹⁵ Similarly, in cardiothoracic surgery, interactive workshops involving guided dissection, surgical skills practice, and talks from surgeons, were shown to successfully increase interest in a career in surgery.^{2,9}

In contrast to previous studies, the results of this study demonstrate that these experiences need not be directly supervised by surgical professionals. The students accessed and used the simulator independently, with only a short introduction delivered by a trainer. Increasing technological advances raises the potential of less labor-intensive practical skills sessions, in which students can learn and practice basic surgical skills, receiving feedback from calculated and predefined metrics. The findings of this study may suggest that the “gamification” achieved by receiving feedback—be it from a surgeon or from a simulator—may be sufficient to stimulate further interest in surgery.

Despite increasing investigation into the potential use of VR simulation in surgical training, there have been few attempts to elucidate trainee and future trainee attitudes to VR simulation's efficacy and efficiency. This

is of particular importance with regard to trainee engagement in potential future simulation training. Social cognitive theory posits that self-efficacy beliefs are the primary drivers for one's desire to engage and use training methods, with authors suggesting that if trainees view their training as unengaging or irrelevant, then it may impact their learning in negative ways.¹⁶ As such, it is important to assess the attitudes of future potential trainees to these new surgical teaching methods. Previous studies have demonstrated markedly positive attitudes toward simulation training among current surgical trainees, with nearly 90% of respondents in one study agreeing that simulators (VR or low fidelity) improved the quality of training and should be mandatory for junior trainees.^{17,18} These results mirror those of this study, which found that the majority of students viewed VR simulation positively. These findings suggested that there would be good engagement of current and future trainees with potential VR simulation programs.

Limitations

However, it should be noted that there are several limitations to the findings of this study. First, it is likely that there was a selection bias present. Similar to previous studies investigating means of stimulating interest in surgical specialities, participants were voluntarily

recruited for this study and opted to sacrifice their own leisure time in order to take part.^{2,9,10} Therefore, it is likely that participants were more likely to be interested in surgery and/or orthopaedics when compared to the general student body. This is reflected in their pre-simulator questionnaire responses; median self-reported interest in surgery and the likelihood of attending the endoscopic and arthroscopic surgical list were greater than 5 (neutral response). This limitation, however, does not detract from the findings of this study. Ensuring students' interest in orthopaedics is strengthened may increase application rates to orthopaedic training programs. Second, the long-term impact of interventions attempting to foster interest in surgical specialities and orthopaedics is unclear. Although many studies have demonstrated increases in self-reported interest in various specialities following career events, practical workshops, and mentorship programs, the number of these students who go on to pursue careers in these specialities is unknown.^{2,9,10} Furthermore, this study took place at a single academic institute with a relatively small sample size. Therefore, it is not known whether these results would be replicable on a larger scale at other medical schools.

Conclusion

These results demonstrate that exposure to VR arthroscopic simulation increased medical students' interest in orthopaedics, surgery, and arthroscopy, without the need for direct supervision. Following VR simulator use, students reported they were more likely to engage with training opportunities, including arthroscopic and endoscopic surgery.

References

- Bartlett J. Addressing the recruitment shortfall in surgery. How do we inspire the next generation? *Ann Med Surg (Lond)* 2018;25:30-32. doi:10.1016/j.amsu.2017.11.024.
- George J, Combella T, Lopez-Marco A, et al. Winning hearts and minds: Inspiring medical students into cardiothoracic surgery through highly interactive workshops. *J Surg Educ* 2017;74:372-376. doi:10.1016/j.j Surg.2016.10.002.
- Green R, Steven R, Haddow K. Declining applications to surgical specialist training. *Bulletin* 2017;99:142-144. doi:10.1308/rcsbull.2017.141.
- Rao RD, Khatib ON, Agarwal A. Factors motivating medical students in selecting a career specialty: Relevance for a robust orthopaedic pipeline. *J Am Acad Orthopaed Surg* 2017;25:527-535. doi:10.5435/JAAOS-D-16-00533.
- O'Connor MI. Medical school experiences shape women students' interest in orthopaedic surgery. *Clin Orthop Relat Res* 2016;474:1967-1972. doi:10.1007/s11999-016-4830-3.
- Correia Lima de Souza L, Mendonça VRR, Garcia GBC, Brandão EC, Barral-Netto M. Medical specialty choice and related factors of Brazilian medical students and recent doctors. *PLoS One* 2015;10. doi:10.1371/journal.pone.0133585.
- Bartlett JD, Lawrence JE, Stewart ME, Nakano N, Khanduja V. Does virtual reality simulation have a role in training trauma and orthopaedic surgeons? *Bone Joint J* 2018;100-B:559-565. doi:10.1302/0301-620X.100B5.BJJ-2017-1439.
- Yiannakopoulou E, Nikiteas N, Perrea D, Tsigris C. Virtual reality simulators and training in laparoscopic surgery. *Int J Surg* 2015;13:60-64. doi:10.1016/j.ijvsu.2014.11.014.
- Bridgeman A, Findlay R, Devnani A, et al. Inspiring the next generation of cardiothoracic surgeons: An easily reproducible, sustainable event increases UK undergraduate interest in the specialty. *Interact Cardiovasc Thorac Surg* 2016;22:106-108. doi:10.1093/icvts/ivv280.
- Tesche LJ, Feins RH, Dedmon MM, et al. Simulation experience enhances medical students' interest in cardiothoracic surgery. *Ann Thorac Surg* 2010;90:1967-1973, discussion 1973-1974. <https://doi.org/10.1016/j.athoracsur.2010.06.117>.
- Royal College of Surgeons of England. Improving Surgical Training (IST). <https://www.rcseng.ac.uk/careers-in-surgery/trainees/ist/>. Accessed September 16, 2018.
- Johns R. Likert items and scales. *Survey Question Bank: Methods Fact Sheet* 2010;1:1-11.
- Khanduja V, Lawrence JE, Audenaert E. Testing the construct validity of a virtual reality hip arthroscopy simulator. *Arthroscopy* 2017;33:566-571. doi:10.1016/j.arthro.2016.09.028.
- National Health Service. Health Research Authority. Do I need NHS ethics approval?. <http://www.hra-decisiontools.org.uk/ethics/>. Accessed January 28, 2020.
- Simões RL, Dorigatti AE, Silveira HJV, et al. Trauma leagues—A novel option to attract medical students to a surgical career. *World J Surg* 2018;42:549-556. doi:10.1007/s00268-017-4190-5.
- Cook DA, Artino AR. Motivation to learn: an overview of contemporary theories. *Med Educ* 2016;50:997-1014. doi:10.1111/medu.13074.
- Walsh CM, Garg A, Ng SL, et al. Residents' perceptions of simulation as a clinical learning approach. *Can Med Educ J* 2017;8:e76-e87.
- Burden C, Fox R, Hinshaw K, Draycott TJ, James M. Laparoscopic simulation training in gynaecology: Current provision and staff attitudes—A cross-sectional survey. *J Obstet Gynaecol* 2016;36:234-240. doi:10.3109/01443615.2015.1060199.