Original Article

Module-Based Arthroscopic Knee Simulator Training Improves Technical Skills in Naive Learners: A Randomized Trial

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Purpose: To compare the effectiveness, in comparison to a control group (C), of module-based training (MBT) and traditional learning (TL) as a means of acquiring arthroscopic skills on an arthroscopic surgery simulator. **Methods:** Thirty health sciences students with no previous arthroscopy experience were recruited and randomized into 1 of 3 groups: MBT, TL, or C (1:1:1 ratio). Participants in MBT were required to independently practice on a VirtaMed ArthroS simulator (VirtaMed AG, Zurich, Switzerland) for a minimum of 2 hours per week, whereas TL received one-on-one coaching by a senior orthopaedic resident for 15 minutes per week. The control group received no training. All groups were assessed at baseline and at 4 weeks based on objective measures generated by the surgical simulator (procedure time, camera path length, meniscus cutting score, detailed visualization, safety score and total score), and subjective ratings scales (Objective Assessment of Arthroscopic Skill [OAAS] global assessment form, and Competency-Based Assessment form). **Results:** Participants in the MBT group trained on average 113 min/week whereas the TL group trained on average 24 min/week. Three-way repeated-measures analysis of variance showed significant group by time interactions for procedure time ($P = .006$), camera path length ($P = .008$), safety score ($P = .013$), total score ($P = .003$), OAAS form ($P < .001$), and Competency-Based Assessment form ($P < .001$). MBT group was superior to C group for procedure time ($P = .02$), camera path length ($P = .003$), total score ($P = .004$), and OAAS form ($P = .021$), but there were no significant post-hoc differences between MBT and TL groups, or TL and C groups after Bonferroni correction. Total practice time explained 37.5% of the final simulator total score variance. **Conclusions:** Knee arthroscopy simulation training with self-learning modules can improve skills in areas such as procedure time, camera path length, and total score in untrained participants compared with a control group. **Clinical Relevance:** Module-based simulation training provides additional training time and improves technical skills in naive health science students. It is hoped that this effect can be preserved and applied to junior resident developing in a busy residency program.

Surgical resident training has traditionally occurred in a master—apprentice-type relationship, with graduated responsibilities until the trainees are expected to perform procedures on their own.[1,2] Given recent changes in the health care system, including reduced operating room time, increased difficulty of procedures, and working hour restrictions, there is less time for residents to learn using the traditional method.[3] Attending surgeons also may face pressures for increased surgical case volumes, leading to less time available for clinical teaching and supervision in the operating room setting. From this shift in the educational environment, there is a need to move away from the traditional master—apprentice model.[4]

Simulation training allows residents to hone their skills in a less-stressful environment, allowing them to

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practice certain steps as many times as necessary to become competent in the skill, all without any risk to patient safety.[5] It also has been noted that simulation training is a superior method of training residents compared with traditional didactic-style lectures.[3] Residents who had never performed arthroscopy and trained via simulation outperformed residents who only received didactic training.[6]

The VirtaMed simulator (VirtaMed ArthroS; VirtaMed AG, Zurich, Switzerland) includes a computerized mentoring program that describes procedures and assesses user skills based on time of completion, instrument path length and iatrogenic injuries. A user enrolled in this mentoring program is progressed through various levels of training by meeting training targets, essentially providing a proficiency-based progression. Targets are set based on community surgeon levels of ability.

The purpose of this study was to compare the effectiveness, in comparison with a control group (C), of module-based training (MBT) and traditional learning (TL) as a means of acquiring arthroscopic skills on an arthroscopic surgery simulator. The study hypothesis was that training in either of the groups (module-based training or traditional learning) would result in improvements in scores over the control group and that the module-based training group would score higher than the traditional learning group on both objective and subjective measures.

Methods

Participants

Thirty students from various health sciences faculties of a Canadian University who were naive to arthroscopic surgery were recruited as a sample of convenience (word of mouth) to participate in the current study. Students were excluded if they had previously performed any part of an arthroscopic surgery, or if they were physically unable to use the simulator. Participants were recruited via e-mail and advertisement. Participants in this study were volunteers and received no compensation for their involvement in the study. Before commencement of the study, approval was granted by the institution's ethics review board.

Study Design

This was a single-blinded (blinded evaluators), parallel, 1:1:1, randomized controlled trial with 3 arms: MBT, TL, or C. MBT received arthroscopic training for 120 minutes per week for 4 weeks via a knee module developed by VirtaMed AG on the VirtaMed ArthroS.[7] TL received arthroscopic training from a senior orthopaedic surgery resident (postgraduate year 4) for a minimum of 15 minutes per week for 4 weeks. C received no training.

Procedures

Before consenting participants, a series of opaque envelopes with group allocation were created, based on a computer-generated series of random numbers. Each participant attended 2 evaluation sessions, 4 weeks apart, and randomization took place at the beginning of the initial session whereby the principal investigator opened the study envelope revealing the group allocation. In the first session, all the participants watched a 16-minute instructional video introducing knee anatomy and arthroscopy. They then completed a questionnaire that included demographic information, hand dominance, interest in surgery, and current or previous experience with video games and musical instruments. They also completed the Box and Blocks Test[8] to assess manual dexterity and a written test of visual spatial ability. They were then individually given a brief refresher (5 minutes) knee anatomy lesson, introduced to a diagnostic knee arthroscopy checklist, and given instruction on usage of the simulator and associated tools. Each participant was then given 10 minutes to familiarize themselves with the simulator.

Participants allocated to the TL group were mentored by 1 of 3 senior orthopaedic surgery residents (fourth year) for 4 sessions over 4 weeks. Because of scarce availability of the mentors, the sessions were planned for a minimum of 15 minutes, but participants were allowed to continue practicing after the resident finished or book additional sessions without an instructor. In session one, participants were given an overview of the tools, taught how to perform the examination of all structures of the knee and were introduced to triangulation. The second session consisted of practice of triangulation skills as well as introduction to loose-body removal and meniscectomy. In the third session, the participant practiced the diagnostic examination with only redirection and guidance from their mentor. Tips and tricks on how to see all of the structures were provided. During the final session, the participant performed a diagnostic examination and double meniscectomy. Only minimal guidance and redirection were provided by their mentor.

Participants allocated to the MBT group received training through the VirtaMed ArthroS internal modules for a minimum of 2 hours per week during their 4-week training period. In their first session, the participants were instructed on how to start the modules by the principal investigator. During the remainder of that session and the ensuing 3 additional sessions, self-directed learning was practiced by the participants with progression through a series of modules. The modules consist of knee basic skills, knee course in diagnostics, and knee advanced course (therapeutic cases). The modules taught the participants to identify and palpate key landmarks as well as how to triangulate the tools. The module system is based on scoring and will only allow a participant to progress to the next module if

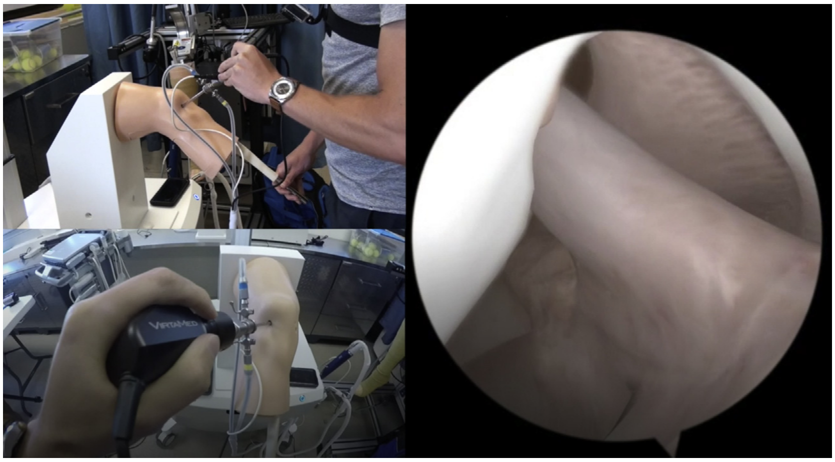

Fig 1. Subjective video analysis setup. Still frame of a video used for subjective analysis of participant's performance. Hand movements were filmed from 2 different angles (top left and bottom left images) and the simulated arthroscopy procedure was recorded (right image). All three videos were synchronized into one file for the evaluators to review.

they have scored high enough. Slower participants were allowed to take more time or book more sessions if needed, whereas faster ones continued on the more-advanced modules (anterior cruciate ligament reconstruction) or continued to practice on previously completed ones until they reached the 2-hour minimum time.

To assess baseline and end-point skills, participants were required to perform a diagnostic knee arthroscopy followed by a double meniscectomy on the VirtaMed simulator. During the procedure, participants' hand movements and the arthroscopic view from the simulation (Fig 1) were recorded. Participants were evaluated both by the internal scoring system on the VirtaMed ArthroS and by 1 of 2 evaluators, a senior orthopaedic resident (fourth year) and a fellowship-trained attending sports orthopaedic surgeon. The evaluators were blinded to the participants' identity and group allocation. A previously validated modified Objective Assessment of Arthroscopic Skill [OAAS] global assessment form for arthroscopy (OAAS, see Appendix Fig 1, available at www.arthroscopyjournal.org)[9] and a modified version of the University of Toronto Orthopedic Program Competency-Based Assessment form (CBA, see Appendix Fig 2, available at www.arthroscopyjournal.org)[10] were used to score the participants. To ensure standardization, a subset of 10 videos were scored by both evaluators, followed by constructive discussion on appropriate scoring criteria.

Outcome Measures

Simulator Scores

All groups were assessed at baseline and at 4 weeks based on objective measures generated by the surgical simulator and subjective rating scales. The primary outcome was the total simulator score (TS), which is a compound score derived from the multiple simulator variables. Other individual simulator variables collected in this study were the procedure time [PT], camera path length [CPL], meniscus cutting score [MCS], detailed visualization [DV] and safety score [SS]. PT is the total time (in seconds) taken to complete the entire procedure. CPL is a measure in centimeters of the total displacement of the tip of the arthroscopic camera. The MCS is a compound score that gives points for adequately removing the torn portions of the meniscus and removes points when healthy meniscus is resected. DV represents the sum of each structures adequately visualized during the diagnostic arthroscopy (2 points for complete visualization, 1 point for partial visualization, and no points if the structure is not visualized). Finally, the SS is a measure of participants ability to avoid damage to the cartilage, by removing points for inadequate contact with the femur or tibial cartilage. These measures have been selected by the authors out of the multiple variables available from the simulator as they seemed to provide face validity for adequate skills in arthroscopic surgery. TS, CPL, and PT have been shown to correlate well with resident training year, providing construct validity.[11-13]

Objective Assessment of Arthroscopic Skill (OAAS)

The OAAS form has been developed as a global rating scale for evaluating arthroscopic surgical skills. It is composed of 8 items rated on a 5-point scale: Examining/Manipulating the Joint, Triangulating instruments, Controlling Fluid Flow and Joint Distension, Maintaining Field of View, Controlling Instruments, Economizing Time and Planning Forward, Overall, and Skill Level (see Appendix Fig 1). The third item (Controlling Fluid Flow and Joint Distension) was removed in this study, as it was difficult to recreate in a simulated setting. The sum of each item constituted the OAAS score. This score has been shown to have strong correlation with training level, good test–retest reliability, and excellent internal consistency.[9]

Table 1. Participants' Characteristics at the First Assessment

Variable	Module-Based Learning	Traditional Learning	Control
Number of participants	10	10	10
Sex			
Male	5 (50%)	4 (40%)	5 (50%)
Female	5 (50%)	6 (60%)	5 (50%)
Age, y	23.8 ± 2.8	25.6 ± 3.4	24.5 ± 5.0
Dominant hand			
Right	9 (90%)	10 (100%)	7 (70%)
Left	1 (10%)	0 (0%)	3 (30%)
Faculty enrolled in			
Kinesiology	3 (30%)	2 (20%)	2 (20%)
Medicine	6 (60%)	5 (50%)	5 (50%)
Med rehab		2 (20%)	
Nursing	1 (10%)	1 (10%)	3 (30%)
Interest in surgery			
None at all	1 (10%)	1 (10%)	0 (0%)
Not very	0 (0%)	1 (10%)	0 (0%)
Neutral	0 (0%)	0 (0%)	1 (10%)
Somewhat	5 (50%)	6 (60%)	6 (60%)
Very	4 (40%)	2 (20%)	3 (30%)
Interest in orthopaedic surgery			
None at all	1 (10%)	1 (10%)	1 (10%)
Not very	1 (10%)	3 (30%)	2 (20%)
Neutral	1 (10%)	1 (10%)	3 (30%)
Somewhat	5 (40%)	2 (20%)	4 (40%)
Very	2 (20%)	3 (30%)	0 (0%)
Have seen an arthroscopic procedure			
Yes	3 (30%)	4 (40%)	3 (30%)
No	7 (70%)	6 (6%)	7 (70%)
Box and Blocks Score			
Right	69.1 ± 8.4 blocks	61.0 ± 5.0 blocks	69.7 ± 7.1 blocks
Left	66.3 ± 6.9 blocks	62.4 ± 6.0 blocks	69.7 ± 6.7 blocks
Visual Spatial Ability Test score	83.4 ± 10.2%	77.3 ± 14.3%	81.8 ± 12.1%
Play video games regularly			
Yes	40% − avg. time spent 7.75 ± 5.3 h	0%	40% − avg. time spent 3.5 ± 4.4 h
No	60%	100%	60%
Draw or Paint			
Yes	0%	20% − avg. time spent 0.50 ± 0.7 h	30% − avg. time spent 1.67 ± 2.1 h
No	100%	80%	70%
Trained on a Musical Instrument			
Yes	80% − avg. time spent 3.31 ± 2.8 h	60% − avg. time spent 1.04 ± 1.2 h	100% − avg. time spent 2.90 ± 2.3 h
No	20%	40%	0%

Competency-Based Assessment Form (CBA)

Recently, multiple Canadian universities have undertaken a switch to a competency-based curriculum. Residents are evaluated more frequently and must demonstrate adequate competency in multiple procedures and clinical settings to progress to the next level.[10] The CBA form used in this study is an adapted version of the form used at the University of Toronto to evaluate residents performing arthroscopic meniscectomy in this setting (see Appendix Fig 2). It is divided into four sections containing multiple items rated on a 5-point scale: Preoperative management (not used in this study), Intraoperative management (13 items), Postoperative management (not used in this study), and Global rating (1 item). The total CBA score is calculated by summing up each individual item. This form has not been previously formerly validated.

Statistical Analysis

Data analysis was performed using SPSS 24 (IBM Corp., Armonk, NY) for Windows. All statistical analyses were 2-tailed with a significance level of .05. No power calculations were performed prior to the beginning of the study. A sample of 10 participants per group was chosen based on feasibility and the number of health science students available to be approached for consent in the current orthopaedic program.

Table 2. Participant Scores at the Initial and Final Testing, With Mean Change in Group Score Reported

Outcome Measure	Time Point	Module-Based Learning	Traditional Learning	Control	Repeated Measures ANOVA - Group × Time Interaction (*P*)
Simulator variables					
Procedure time, s	Initial testing	1039.1 (224.3)	1047.2 (225.4)	1005.0 (258.0)	
	Final testing	578.4 (253.4)	824.4 (216.4)	1043.1 (191.7)	
	Change	−460.7 (396.1)	−223.2 (358.6)	38.2 (129.7)	.006
	Sig (*P*)	.005	.081	0376	
Camera path length, cm	Initial testing	389.6 (175.5)	438.7 (202.4)	489.4 (258.3)	
	Final testing	139.2 (45.4)	266.0 (161.0)	558.6 (201.1)	
	Change	−250.5 (173.5)	−172.6 (229.0)	69.2 (249.5)	.008
	Sig (*P*)	.001	.041	.403	
Meniscus cutting score	Initial testing	25.4 (6.6)	23 (6.1)	24.2 (9.3)	
	Final testing	33.6 (5.0)	34.5 (7.2)	31.8 (5.2)	
	Change	8.2 (10.1)	11.5 (5.1)	7.6 (9.1)	.543
	Sig (*P*)	.031	<.001	.027	
Detailed visualization	Initial testing	19.4 (3.6)	19.1 (3.4)	19 (4.9)	
	Final testing	23 (2.6)	22.8 (3.8)	18.1 (7.4)	
	Change	3.6 (3.9)	3.7 (3.8)	−0.9 (5.8)	.052
	Sig (*P*)	.016	.013	.634	
Safety score	Initial testing	17.5 (2.3)	18 (2.1)	18.3 (1.6)	
	Final testing	18.7 (1.3)	17.8 (1.5)	15.8 (1.9)	
	Change	1.2 (3.0)	−0.2 (2.3)	−2.5 (2.5)	.013
	Sig (*P*)	.239	.794	.011	
Total Score	Initial testing	98.4 (12.3)	96.4 (14.0)	96.2 (15.5)	
	Final testing	127 (12.3)	117.6 (18.0)	96.6 (8.7)	
	Change	28.6 (20.1)	21.2 (17.4)	0.4 (17.4)	.005
	Sig (*P*)	.001	.004	.944	
OAAS Global Assessment Form[9]					
Total summed score	Initial testing	10.00 (2.906)	9.40 (2.221)	11.10 (1.853)	
	Final testing	18.80 (4.211)	14.90 (3.213)	11.20 (3.120)	
	Change	8.80 (3.882)	5.50 (3.028)	0.10 (3.281)	<.001
	Sig (*P*)	<.001	<.001	.925	
Competency-Based Assessment Form[10]					
Total summed score	Initial testing	17.70 (4.923)	17.60 (4.169)	21.10 (3.510)	
	Final testing	33.50 (6.671)	28.80 (6.374)	20.70 (6.325)	
	Change	15.80 (7.657)	11.20 (6.460)	−0.40 (6.059)	<.001
	Sig (*P*)	<.001	<.001	.839	

NOTE. Results shown as mean (standard deviation). Tests for between-group differences with repeated-measures ANOVA.
ANOVA, analysis of variance; OAAS, Objective Assessment of Arthroscopic Skills.

Descriptive statistics for all variables were calculated and repeated measures analysis of variance with interaction effects of time and study group were conducted. Post-hoc pairwise comparisons were conducted on significant outcomes and were Bonferroni corrected.

A series of exploratory stepwise linear regression analyses were performed on the whole sample to examine the effects of demographic variables and participants past experiences on initial and final total simulator scores. For the initial scores, the following variables were entered in the model: age, sex, dominant hand, playing a musical instrument, drawing or painting, playing video games, studying in medicine, interest in surgery, interest in orthopaedic surgery, number of previous arthroscopic surgeries seen, Box & Blocks test results (right and left hand) and VSA test scores. Initial simulator total score, total practice time, and group assignment were added to regression analyses for final scores.

Results

Thirty participants consented to the study with a mean age of 24.6 ± 3.9 years, with 47% male (53% female) and 86.6% right-handed. Demographic information is presented in Table 1 and groups were similar on all parameters. There were 16 medical students in the sample. In total, 86.7% of participants rated their interest in surgery at 4 or greater on a 5-point Likert scale; and 53.3% rated their interest in orthopaedic surgery similarly.

Participant scores at baseline and final testing are presented in Table 2.[9,10] Participants in the MBL group trained on average 113 min/week, whereas the TL group trained on average 24 min/week, over 4 weeks. Every participant in the MBT groups completed the required modules. No participant in either the TL or MBT group booked additional training sessions. There was a significant improvement from baseline to final assessment scores in the MBT group on PT, CPL, MCS, DV, TS, OAAS, and CBA scores. The TL group showed improvement in CPL, MCS, DV, TS, OAAS, and CBA scores. The control group showed only an improvement in MCS and a decrease in SS.

Repeated-measures analysis of variance demonstrated significant interactions between the effects of group and time point for PT (F[2, 27] = 6.179, P = .006), CPL (F[2, 27] = 5.758, P = .008), SS (F[2, 27] = 5.074, P = .013), and TS (F[2, 27] = 6.363, P = .005). On post-hoc pairwise comparisons with Bonferroni correction, MBT group was superior to C group for PT (P = .02), CPL (P = .003), and TS (P = .004), but the difference on SS was no longer significant There were no differences seen between MBT and TL groups, or between TL and C groups on any outcomes. Similarly, subjective scores showed significant interactions between the effects of group and time point for both TS on the OAAS Global Assessment Form (F[2, 27] = 16.534, P < .001) and CBA from (F[2, 27] = 15.254, P < .001). On post-hoc testing, the MBT group was superior to the C group on the OAAS test (P = .021), but there was no significant difference between MBT and TL or TL and C group. No significant post-hoc interactions were found on the CBA summed score.

Significant regression models were found for both initial and final total simulator scores. Age explained 18.2% of the variance in the initial simulator score (F [1, 28] = 7.461, P = .011). Total practice time explained 37.5% of the total final simulator score variance (F[1, 28] = 18.364, P < .001), while incorporating "playing a musical instrument" into the model explained an additional 12.6% (F[2, 27] = 15.546, P < .001).

Discussion

The principle finding of this study was that both a 4-week knee arthroscopic simulation training program (MBT) using self-learning modules and 4 weeks of traditional apprentice-master style teaching (TL) improved performance on a simulator. There were no differences in the magnitude of improvement between these 2 approaches; however, only the simulation training program improved scores statistically more than those that received no training (C). Participants in the MBT group were able to reduce the time needed to perform the procedure, reduce the camera path length throughout the procedure, and increase the total score compared with the C group. Low power may have prevented from detecting a significant difference between TL and C groups, and MBT and TL groups. This is consistent with the current literature, showing that simulation training in orthopaedics can significantly improve performance on the simulator.[14-20] Dammerer et al.[14] found that simulation training improved skills in not only untrained medical students but also in orthopaedic surgery residents. It is still unclear whether the skills learned through simulation translate into clinically relevant surgical skills, as the minimal clinically important difference of available arthroscopy competency assessment tools is not known.

The design of the study led to a large difference in training time between MBT and TL. When all the participants were pooled together in a regression analysis, training time was a significant factor explaining final score variance. To lessen this difference in training time, a longer training period could have been selected. Nonetheless, the investigators decided against it, as it would significantly lengthen the data collection and put more burden on the study participants and scarcely available senior resident mentors. Despite the fact that the MBT group trained 5.5 times longer than the TL group (113 min/week vs 24 min/week), there were surprisingly no significant differences between these 2 groups. While this may be due to a lack of power in the study, another explanation could be that simulation training may not be as efficient a learning tool than the valuable information passed along to the learner from an "expert" teacher. In the clinical setting, it is, however, more likely that both methods will be coupled together, with learners supplementing their time spent with a mentor by practicing on their own with the simulator. Angelo et al.[21] found that simulator training, when coupled with a proficiency-based progression, resulted in significantly improved skills to repair a Bankart lesion arthroscopically in comparison with both no simulation training and simulation training with no proficiency-based progression. This supports the idea that simulation training may be more effective when coupled with traditional training.

There are some major limitations in the use of a simulator to develop arthroscopic skills. It has been previously commented that simulation training allows a learner to learn the skills required to perform arthroscopy but does not teach the learner the procedure itself.[22] Frank et al.[23] comment on the numerous essential skills that simulation training fails to train in any manner, such as portal placement and fluid management. Safety during the surgical procedure may also be difficult to train on the simulator. Interestingly, the simulator safety score showed no improvement in either training group when compared with the control group. Cychosz et al.[24] found similar results in their study, where residents did not show any improvement in cartilage damage on a cadaver after both their training and control groups practiced on a nonanatomic simulator. In the ArthroS software, the safety score is calculated by removing points if the learner touches or scratches the femoral or tibial cartilage accidentally or removes too much meniscus. This score does not put any weight in how much pressure is applied to the cartilage and might not represent actual injury. In contrast, evaluators look at the participant's general movement and if they seem to intentionally avoid the cartilage, for example by inserting the instruments in the notch and moving them along the periphery to avoid any accidental damage to the cartilage. These methods are not taught or measured directly in the simulator modules. Despite its shortcomings, there has been some evidence that simulator training can translate into improvement in skills in an operating theater.[25,26] The use of simulation training is, however, not a necessity, as it has been shown that over the course of training, residents that had no simulation training eventually reached the level of the simulator trained residents.[27] That being said, simulator training may provide enhanced skills to improve patient safety overall, as residents may become more skilled earlier in their training, leaving more time for the mentor to teach more advanced skills.

Initial simulator test scores were only significantly influenced by the age of the participants. However, after training, only the total practice time and having played a musical instrument explained variance in the final simulator test scores. Pre-tests, such as the Box & Block test and visual special ability test, had no effect on the initial or final score. Previous literature is conflicting on the usefulness of these kinds of tests to select potential candidates for a surgical residency position.[28] Other variables, such as age, sex, dominant hand, previous video game experience, engaging in drawing or painting, and interest in orthopaedic surgery, had no significant effect. Testing potential residency candidates with a simulator would be low yield in a selection process as initial scores were not shown to influence the final scores. It is more evident from this data that practice is the most important determinant of final skills, and that candidates from any background, given sufficient practice time, can become proficient in arthroscopy. Participants who played instruments did marginally better than those who did not, which is consistent with a study showing that musical experience improved skills in laparoscopic suturing.[29]

One major strength of this study was that group allocation of participants was randomized. Evaluators performing the subjective assessment were blinded to the group allocation of participants in an attempt to eliminate bias. The current study also used only naive learners to ensure that all participants were starting at a beginner level, and that there was not a varying degree of skill level between participants, as would be the case when using residents.

Limitations

One limitation of our study is that time spent training on the simulator was not taken into consideration in the primary analysis because it was dependent on the assigned group. Training time of the MBT group was 5.5 longer than the TL group and accounted for a significant portion of the final simulator score variance in the regression analysis. Scarce availability of instructors limited the total amount of practice time to the TL group to only 15 minutes a week; meanwhile, the MBT group did not require instructors and so participants could practice for significantly longer periods. Three different clinical instructors mentored the TL group, adding some heterogenicity to this group's training experience, possibly impacting the data. This, however, may be a better reproduction of the residency setting, where multiple attendings may be involved in a resident's arthroscopy rotation. In addition, the sample size used was likely not powered enough to avoid type II error on post-hoc testing or regression analysis. Significant differences between MBT and TL group, and TL and C group, may have been detected if a larger sample had been used. The use of health science students instead of junior residents or medical students interested in orthopaedic surgery also limits the applicability of the results to residency training. However, the authors believe that using naive learners helps strengthen the argument that practice by simulation can improve the skills of even the ineptest of learners.

Conclusions

Knee arthroscopy simulation training with self-learning modules can improve skills in areas such as PT, CPL, and TS, in untrained participants compared with a control group. Total practice time and playing a musical instrument were linked with better simulator scores. This supports module-based simulation training as a safe method to provide additional time and practice to improve arthroscopic skills.

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