RESEARCH ARTICLE

A Randomized Controlled Pilot Study of Educational Techniques in Teaching Basic Arthroscopic Skills in a Low-income Country

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Abstract

Background: Little is known about how to introduce complex technologies like arthroscopy into low-income countries. Thus, we compared low- versus high-resource intensive methods of teaching basic arthroscopic skills in a randomized controlled trial in Haiti.

Methods: Forty-eight Haitian orthopaedic surgeons and residents attending an orthopaedic conference in Haiti were block randomized to receive instruction through a composite video (Control) or a composite video plus hands-on teaching with an expert visiting surgeon (Intervention). A low-fidelity surgical simulator tested visualization and triangulation skills. Participants completed a pre- and post-test where the goal was to sequentially tap the most numbers in 2.5 minutes. Outcome metrics included highest tapped number, number of errors, visualization loss, and number of lookdowns. Multivariate linear regression was used to confirm randomization and compare outcomes between groups.

Results: Seventy-five percent of initially randomized attendees participated with similar attrition rates between both groups. All participants who performed a pre-test completed a post-test. In terms of highest tapped number, treatment and control groups significantly improved compared to pre-test scores, with mean improvement of 3.2% (*P=0.007*) and 2.2% (*P=0.03*), respectively. Improvement between treatment and control groups was not statistically different (*P=0.4*). No statistically significant change was seen with regard to other metrics.

Conclusion: We describe a protocol to introduce basic arthroscopic skills in a low-income country using a low-resource intensive teaching method. However, this method of learning may not be optimal given the failure to improve in all outcome measures.

Keywords: Arthroscopy, Developing country, Education technology, Simulation, Surgical education

Introduction

The role of arthroscopy in low-income countries is not well defined. The majority of orthopaedic literature related to surgical intervention in the developing world focuses on the treatment of musculoskeletal trauma with open techniques (1-4). Limited literature conveys the need for arthroscopy in the developing world, yet arthroscopy can be used to diagnose and treat a rising burden of trauma- and sports-related injuries (5, 6). In the future, arthroscopy may be used in these nations as a tool to manage devastating shoulder and knee instability that happen at work and often keep patients out of work (7). These injuries are prevalent in low-income countries and account for significant disability. For example, in countries where arthroscopy is common, it is used as an adjunct to articular fracture care in the knee, wrist, calcaneus and elsewhere (8-12). In addition, arthroscopy may be a useful diagnostic tool for patients in settings where advanced imaging is unobtainable.

Recent literature suggests that arthroscopy may be

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introduced into low-income countries after methods to control the burden of disease from musculoskeletal injury and infection are established (13). Yet, little is known about how to introduce new surgical technologies into poorer countries like Haiti. The orthopaedic literature does offer principles of appropriate technology transfer to developing countries, but a description of methods for technology transfer is noticeably absent (2, 13).

In addition to patient need, local orthopaedic surgeons are also hopeful for the introduction of arthroscopy. A recent needs assessment conducted in Haiti identified arthroscopy as the skill which local orthopaedic surgeons most wanted to learn (14). Given this interest, we devised a teaching protocol using a previously validated portable simulator to begin introducing basic arthroscopic skills to Haiti based on the Fundamentals of Arthroscopic Surgery Training (FAST) curriculum (15).

In this randomized controlled pilot study, our aim was to compare two methods (low and high resource) of introducing basic arthroscopic skills training in Haiti. We hypothesized that both standardized lecture/video presentations alone (low-resource intensity) and in combination with expert instruction (high-resource intensity) would improve baseline performance, but teaching transfer from expert instruction would be superior to that from a lecture/video alone.

Materials and Methods

Study type: Prospective randomized controlled trial

Setting: Our study was conducted during the Haitian Annual Assembly for Orthopaedic Trauma (HAAOT) over a single session in April 2015.

Subject enrollment: This study received IRB exemption from our hospital's Institutional Review Board. Eligible subjects were Haitian orthopaedic surgery residents and attending surgeons who attended the conference. Lottery tickets to win a prize were provided as an inducement for participation and improved performance.

Study design [Figure 1]*:* Forty-eight Haitian orthopaedic residents and attending surgeons were block randomized

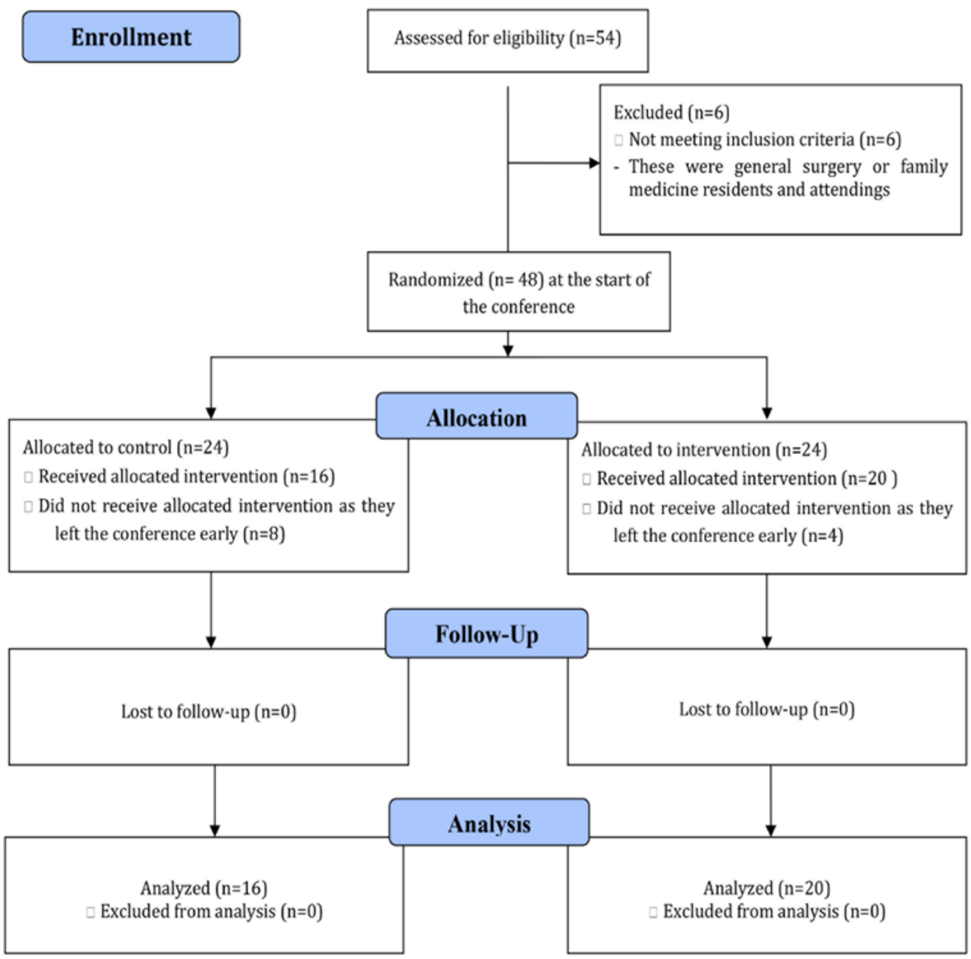

Figure 1. Flow diagram of subject enrollment.

at the start of the conference to receive skills instruction. The random allocation sequence was created and concealed until after intervention was assigned using labeled notecards. The intervention consisted of a 5-minute description of general arthroscopic principles followed by 10 minutes with an expert on the simulator demonstrating appropriate techniques in visualization, triangulation, and hand-eye coordination. The control consisted of a composite teaching video alone. All participants initially received skills instruction through a 10-minute video presentation based on the freely available FAST videos (http://www.aana.org/FASTProgram/Overview). All participants then completed a pre-test on a previously validated, low-fidelity surgical simulator for basic arthroscopy (Sawbones, Vashon Island, Washington) (15). The simulator consists of an arthroscopic camera, computer monitor, arthroscopic probe, and an opaque box covering a construct with numbers arranged randomly from 1 to 21 [Figure 2].

Participants were instructed to sequentially tap the most numbers they could within 2.5 minutes while maintaining visualization of the probe tip to test visualization and triangulation skills. Following the pre-test, the intervention group received additional hands-on instruction with an expert. Both groups were able to reference the instructional video between their pre- and post-tests. Both groups then completed a post-test.

Outcome measures: Previously validated metrics used for outcome assessment included highest number tapped sequentially, number of errors (unintentionally tapping any areas outside of the numbered tags), visualization loss (number of times probe tip was lost from field of view), and number of look-downs (physically turning eyes away from monitor and looking down at operator's hands) (15-16). Visualization loss and number of look-downs were assessed by a PGY-3 or PGY-4 United States-based orthopaedic surgery resident. Demographic data, including trainee level, experience with arthroscopy, surgical-handedness, and participation in video game play was also recorded.

Statistical analysis: Data was analyzed using STATA/IC13. Multivariate linear regression was used to compare demographic data between groups to confirm randomization and to compare outcome metrics. A *P-value* less than 0.05 was considered statistically significant.

Results

Demographics

In total, forty-eight orthopaedic surgeons and residents (100% of eligible participants) consented to participate in this study at the start of the conference and were randomized. Twenty-five percent of subjects who were randomized at the beginning of the conference

Figure 2. Arthroscopy simulator module setup.

Table 1. Characteristics of the study sample demonstrating similar distribution between groups [a]

	(%) No./Total		
Characteristics	**Total (n=36)**	**Control (n=16)**	**Intervention (n=20)**
Male sex	34/36 (94.4)	16/16 (100)	18/20 (90)
Resident	29/36 (80.6)	12/16 (75)	17/20 (85)
Prior arthroscopy experience	8/36 (22.2)	6/16 (37.5)	2/20 (10)
Right-hand dominance	33/36 (91.2)	14/16 (87.5)	19/20 (95)
Plays video games	19/36 (52.8)	9/16 (56.2)	10/20 (50)
Age, mean (SD)	32.6 (5.7)	34 (7.3)	31.5 (3.8)

[a] No significant differences between groups were found in any of these characteristics

had left the conference before the study started. All participants who performed a pre-test completed a post-test. Randomization was successful with no significant differences in demographic characteristics [Table 1]. To summarize, 80.6% of participants were residents, 22.2% had participated in at least one arthroscopy case before, 91.2% were right-hand dominant, and 52.8% endorsed playing video games. Mean age (+/- standard deviation) was 32.6 +/- 5.7 years.

Highest tapped number

The primary outcome measure was "highest tapped number," defined as the highest number reached by task time completion at 2.5 minutes. When compared to pre-test scores, both intervention and control groups improved on average by 3.2% (*P=0.007*) and 2.2% (*P=0.03*), respectively [Figure 3]. Improvement between intervention and control groups was not statistically different (*P=0.4*).

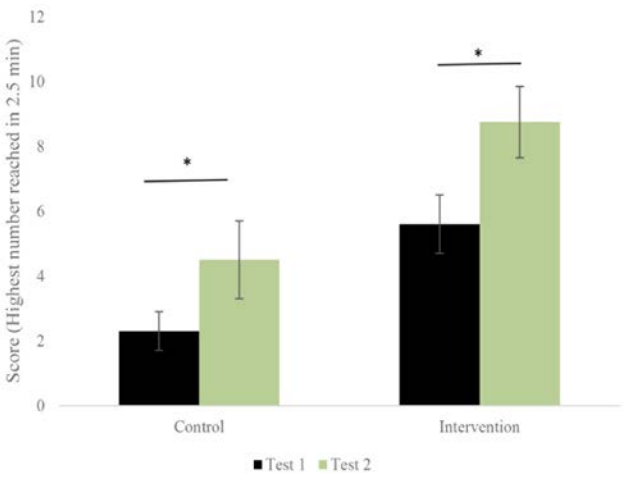

Figure 3. (a) Completion (highest tapped number) comparison between intervention and control groups. Statistically significant improvement (*p<0.05) in both groups, but not different between groups.

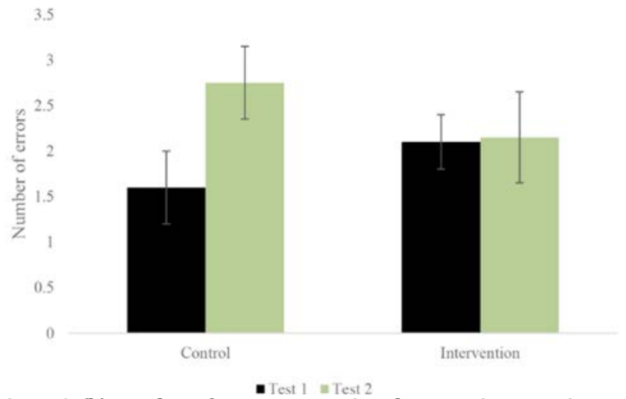

Figure 3. (b) Number of errors comparison between intervention and control groups. No statistically significant change within or between groups.

Other outcome measures

No statistically significant change in number of errors, visualization loss, or look-downs was observed within or between treatment and control groups [Figure 3b-d].

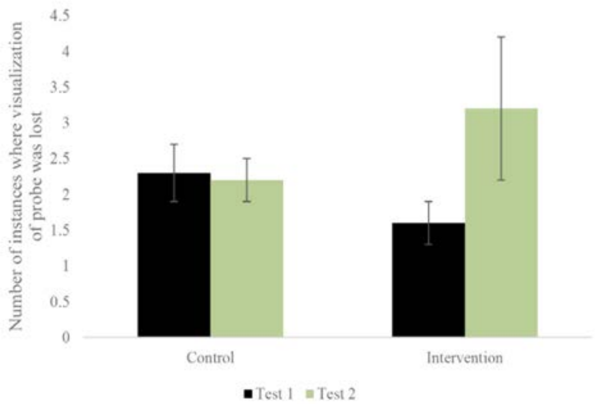

Figure 3. (c) Visualization loss comparison between intervention and control groups. No statistically significant change within or between groups.

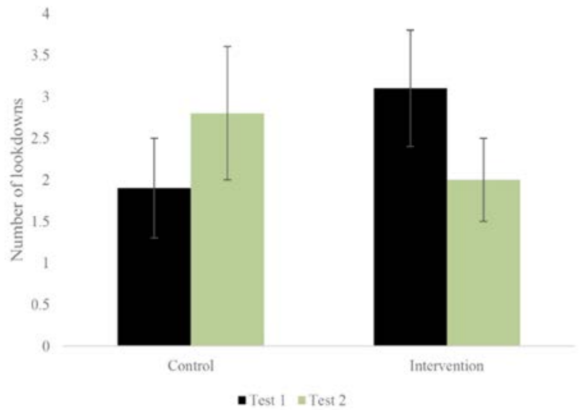

Figure 3. (d) Number of lookdowns comparison between intervention and control groups. No statistically significant change within or between groups.

Cost analysis of the teaching protocol

We also compared the true budget costs for the low-resource (control) and high-resource (intervention) groups. Ranges in Table 2 are provided for (1), (2) and (3) based on observed price variation at the HAAOT conference over the two previous years. We find that the addition of an expert visiting orthopaedic surgeon traveling to Haiti specifically for an arthroscopic teaching program and working as a volunteer without pay increases the cost of the low-resource teaching protocol by approximately 29-39%; however, this data is specific to the location of our conference and the length of stay. During the time period of our study, this cost was reimbursed by departmental funds or conference funding provided by sponsors.

Table 2. Cost analysis between low-resource (control) and high-resource (intervention) group

	Control	Intervention
FAST Arthroscopy Workstation Bundle	3344.5	3344.48
Miscellaneous supplies (paper, stopwatches, pens)	20	20
FAST videos	0	0
(1) Flight for visiting expert orthopaedic surgeon	---	700-900
(2) Housing for visiting expert orthopaedic surgeon (~$100-150/ night, 2 nights)	---	200-300
(3) Expenses for visiting expert orthopaedic surgeon (~$40-60/day, 2 days)	---	80-120
Total Cost ($)	3364.5	4344.48-4684.48

Discussion

Musculoskeletal trauma is the primary focus of orthopaedic surgical intervention in low-income countries, but efforts exist to introduce arthroscopy (13). In this study, we describe a protocol based on the FAST curriculum to teach basic arthroscopic skills in Haiti. The most important result from our study is that we did not find a statistically significant incremental benefit of high-resource methods (expert instruction) over low-resource methods (video/lecture). However, we also find that low-resource methods may not result in optimal technique. In the pursuit of increasing speed, we observed that many participants did not focus on precision and purposeful movement. Quantitatively, this was reflected in the lack of improvement in three other outcome measures.

More broadly, our study addresses the mechanics of teaching basic skills required to implement and utilize a complex technology like arthroscopy. We also examined two teaching methods that differ in resource intensity and cost, as these are relevant for low-income countries like Haiti which have developed infrastructure for the management of musculoskeletal trauma and infection, but are resource-constrained in expanding orthopaedic capabilities. Using a cost analysis specific to our study location and duration, we demonstrated that a high-resource method can increase costs by 29-39%. This can further increase the difficulty in introducing arthroscopy in low-/middle-income countries. Beyond quantitative outcome measures, our program engendered great excitement for orthopaedic education among participants by meeting their expressed desire to learn basic arthroscopy (14). We believe responding to participant feedback in this manner is critical to sustaining orthopaedic education programs in low-income countries.

Our study fits within the current literature describing the introduction and teaching of new techniques. A similar RCT by Leopold *et al.* examined the process of teaching a simple surgical task (superolateral knee injection) utilizing a printed manual, video or hands-on instruction (17). Performance improved significantly in all three training groups without a significant difference in improvement between high and low labor-intensive teaching techniques. However, they noted that their study was limited to the teaching of simple surgical tasks, and specifically excluded relevance to techniques like arthroscopy. Our study extends their results by finding similar improvements in basic arthroscopic skills (a complex surgical task) using high and low-labor intensive techniques. Our study's findings of improvement after a short training course are also similar to outcomes from other studies using an endoscopic virtual reality surgical simulator (18).

Limitations

While our study demonstrates equivalent performance improvement on an arthroscopic simulator using both low- and high-resource intensive methods, our study has several limitations. First, while performance improved in terms of highest tapped number, lack of improvement in other outcome measures intended to track triangulation and visualization precision may indicate that participants failed to learn ideal technique. This is relevant, as studies by Strom et al. have shown that it is important to introduce good practices early before negative ones are ingrained (18). In addition, improved performance may not translate to enhanced outcomes on more complex simulators or in operative performance based on the results of prior studies, although this is controversial (16, 19). We also note that our study was aimed at evaluating meaningful, i.e. large, improvements between intervention and control groups but was not powered to detect smaller levels of difference. Further study is needed with larger samples for validation, but given the high cost differential between video and live in-person teaching, only a marginal improvement with in-person teaching may not be financially justified for teaching beginner skills like operating the camera and using an arthroscopic probe. In addition, low-income countries like Haiti only graduate a small number of residents per year (a maximum of 12 at present), so our study with forty-eight orthopaedic resident and attending surgeons already represents a large population in this context for a single-country study. Lastly, while our study demonstrates initial improvement, it is unclear if this learning persists over the long-term (20).

We describe a potential low-resource intensive protocol using video alone for learning basic arthroscopic skills in Haiti, and we do not find significant incremental benefit of higher resource methods involving hands-on expert instruction.

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