Improving Clinical Performance Using Rehearsal or Warm-up: An Advanced Literature Review of Randomized and Observational Studies

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Abstract

Purpose

To determine whether rehearsal (the deliberate practice of skills specific to a procedure) or warm-up (the act or process of warming up by light exercise or practice) prior to performing complex clinical procedures on patients can improve the task performance of operators and operating teams.

Method

The authors performed an advanced literature search for clinical studies published between 1975 and October 2012 using MEDLINE, EMBASE, the Cochrane Controlled Trials Register, ISI Web of Knowledge, and clinicaltrials.gov. They identified randomized controlled trials and observational studies that evaluated the effects of physical rehearsal or warm-up prior to performing complex clinical procedures. Two reviewers independently reviewed titles and abstracts and then full texts before abstracting data using a standardized form. They resolved disagreements by consensus.

Results

The authors identified 1,886 potential articles and included 7 in their review (2 randomized controlled trials and 5 observational studies). All reported that rehearsal or warm-up by operators or operating teams is feasible. Only two clinical studies objectively demonstrated that warm-up can improve overall technical performance. Other objective evidence supporting the positive effects of rehearsal or warm-up for other team or nontechnical outcomes was limited.

Conclusions

The potential benefits of and optimal techniques for performing physical rehearsal and warm-up have not been established. Preliminary findings suggest that preoperative rehearsal or warm-up can improve the performance of operators or operating teams, but there is a paucity of objective evidence and comparative clinical studies in the existing literature to support their routine use.

Deficiencies in patient safety and quality improvement are increasing concerns with the growing complexity of patient care. Safe medical care requires that complex patient interventions be performed by highly skilled operators (i.e., physicians performing medical interventions requiring technical skills) supported by reliable teams. Operators need to have a low tolerance for error and to be supported by resilient, patient-centered teams in structured microsystems.[1] Differences in the abilities of individual medical professionals are evident, and some, although competent, never attain the skill level of an expert.[2] Although increasing experience plays an essential role in achieving proficiency, its accumulation does not guarantee that expertise will be attained or sustained. Before performing an invasive procedure, the operator or operating team must not only have achieved the required competencies but also be mentally alert and prepared to undertake the complex tasks required of them.[3]

In 1993, Satava[4] described the use of virtual reality simulation for surgical training. Since then, technological innovations have contributed to improved educational outcomes and patient care.[5] Simulation has provided additional opportunities for trainee and expert operators to practice specific procedures, or related skills, prior to performing complex tasks on patients. Simulation ranges from low-fidelity platforms for improving manual dexterity skills to high-fidelity virtual reality for patient-specific procedure rehearsal. Whereas the benefits of training using simulators have been well established,[6,7] preoperative rehearsal and warm-up have only recently been recognized as methods for improving operator or operating team performance, thus improving patient safety.[8,9]

Rehearsal is the deliberate practice of technical and nontechnical skills specific to a procedure, whereas warm-up is "the act or process of warming up for a contest, by light exercise or practice."[9] In baseball, for example, prior to entering the game, a pitcher warms up in the bullpen by stretching his arm; in contrast, he rehearses by practicing the different pitching techniques he will use with specific batters that inning. Although these techniques overlap, warm-up differs from rehearsal because it may be conceptually remote from the proposed procedure and uses both near and far transfer of skills to improve subsequent psychomotor performance. For example, in medicine, a cardiologist using a high-fidelity simulator to place virtual stents prior to performing a coronary artery angiogram is considered rehearsal, whereas using a low-fidelity simulator to practice manual dexterity skills prior to arterial cannulation is considered

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warm-up. In health care, the practice of motor or mental exercises not specific to a procedure, when undertaken immediately prior to the task being performed, is also considered warm-up.

The rationale for physical rehearsal and warm-up is based on motor control and learning theory.[10,11] These methods aim to improve the operator and/or operating team's performance by improving manual dexterity, mental agility, confidence, communication, and workflow. Rehearsal also may improve operator knowledge of patient-specific anatomy and consequent technical demands. Rehearsal and warm-up are gaining increasing recognition as important processes in enhancing operating team performance and improving patient safety, whether for acquiring competencies or maintaining procedural and technical proficiency.[12]

The purpose of this advanced literature review was to determine whether rehearsal or warm-up prior to performing complex clinical procedures on patients can improve task performance as measured by assessments of the technical and nontechnical skills of the operators and operating teams. We hypothesized that rehearsal or warm-up prior to performing complex clinical procedures on patients would improve operators' task performance and reduce procedural errors and patient harm.

Method

We developed a standardized protocol for the conduct of this review. We followed the guidelines for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions.[13,14]

Data sources

We searched MEDLINE, EMBASE, and the Cochrane Controlled Trials Register (via OVID) for all articles published in any language between 1975 and October 2012. To minimize publication bias, we searched ISI Web of Knowledge for unpublished abstracts, as well as the clinicaltrials.gov registry for unreported studies. We also searched the bibliographies of all the included articles to ensure that we did not miss any relevant articles. Next, we contacted the authors of the articles we identified during our literature search (both those included and those excluded from our review) and invited them to suggest other published or unpublished research that we may have missed. In addition, we contacted the corresponding authors of the included articles as needed for additional sources of information, or unpublished data, in regard to their studies. Finally, we contacted the manufacturers of the simulation platforms used in the included articles for information regarding other unpublished trials or gray literature on rehearsal and warm-up.

Search strategy

The primary outcome we sought to identify in each article was an assessment of technical skills. The secondary outcomes were the measurement of differences between control and intervention groups in (1) nontechnical skills, including mental alertness, (2) procedural time(s), and (3) procedural error(s).

We included all clinical studies, using either randomized or observational study designs, that evaluated the effect on operators' and/or operating teams' task performance of formal rehearsal or warm-up completed immediately prior to performing any complex clinical procedures on patients. We defined an operator as any physician (e.g., anesthetist, cardiologist, gastroenterologist, surgeon) performing a medical intervention requiring technical skills and an operating team as any interventional team that included a physician performing a medical procedure. We did not restrict articles by the type of patient or the setting where the study was performed, but we did exclude animal studies, reviews, and editorials.

We used a combination of key words and medical subject heading (MeSH) terms related to rehearsal, warm-up, simulation, and task performance to guide our search strategy. Our initial search strategy using filters for study design provided incomplete results. To provide more comprehensive results, we combined the search terms for the intervention and the outcome, using MeSH terms when possible. We did not restrict articles by language.

Two authors (J.D.O., O.O.) independently reviewed the titles and abstracts generated by the comprehensive literature search to identify articles for inclusion. The same two authors independently reviewed the full texts of the studies deemed potentially eligible to make a final determination about study eligibility. The reasons for excluding articles included nonclinician populations (e.g., medical students), nonclinical outcomes (e.g., simulated outcomes), and nonphysical rehearsal or warm-up interventions (e.g., mental warm-up). When they disagreed, a consensus opinion was reached or a third investigator (G.D.S.) was consulted to resolve any dispute.

The same two authors (J.D.O. and O.O.) independently extracted data using a template modified from the Cochrane Consumers and Communication Review Group data extraction template.[15] Data extracted included publication details (year, authors, and source), methodology (aims, study design, recruitment, inclusion/exclusion criteria, consent, funding, and statistical analysis), participants (description, location, setting, number, age, gender, and other details), interventions (description, delivery, providers, quality, and fidelity), outcomes (primary/secondary, methods, timing, and adverse events), results (dichotomous and continuous outcomes), and risk of bias (random sequence generation, allocation concealment, types of blinding, incomplete outcome data, selective reporting, and other sources of bias). We assessed the methodological quality of the observational studies using the Newcastle–Ottawa Quality Assessment Scale for cohort studies.[16]

A complete description of the search strategies used and the data extraction template are available from the corresponding author on request.

Data presentation

In the Results, we reproduce the numerical data directly from the respective articles. We present parametric data as mean (standard deviation), nonparametric data as median (range), and proportions as percentages.

Results

Search results

Our search yielded 1,886 articles (see Figure 1). During the title/abstract review, we excluded articles that did not

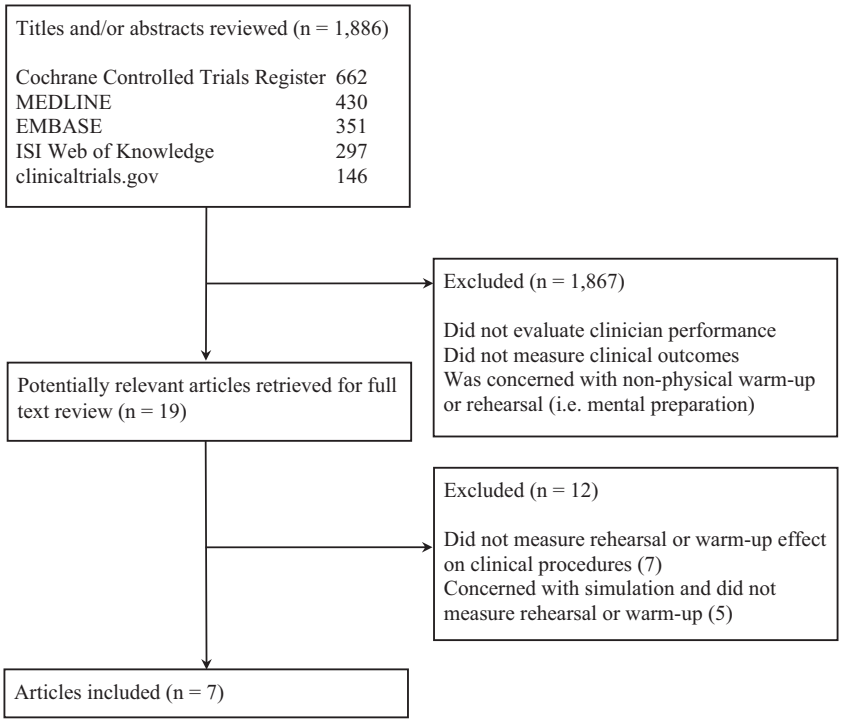

Figure 1 Flowchart of the literature search and article selection process in an advanced review of the literature on the effects of rehearsal and warm-up on clinical performance published between 1975 and October 2012.

meet the inclusion criteria and those that were duplicates. Of the 19 articles for which we reviewed the full text, we excluded 12—7 did not measure the rehearsal or warm-up effect on clinical procedures,[17–23] and 5 were concerned with simulation and did not measure rehearsal or warm-up.[24–28] Seven articles met all the inclusion criteria, evaluating the effect of rehearsal or warm-up on clinical performance.[8,29–34] We agreed on all article inclusion decisions.

Two studies were randomized controlled trials (RCTs).[31,34] The remaining 5 included a cohort study,[33] a case series,[29] and 3 case reports.[8,30,32] Characteristics of the included studies are provided in Table 1. A meta-analysis was not possible because of the heterogeneity of the study designs and outcomes measured.

Quality of included studies

The quality of the included studies varied considerably according to study design. We report the quality of the observational studies in Table 2 and of the RCTs in Table 3.

Effects of interventions

Technical outcomes: Laparoscopic surgery. Both RCTs of the effect of warm-up on surgeons performing laparoscopic surgery reported improvements in technical outcomes for clinical procedures, but these findings were not consistent for all tasks.[31,34] Using the Objective Structured Assessment of Technical Skills global rating scale, Calatayud and colleagues[31] found a significant improvement in overall performance when surgeons used a warm-up before performing a laparoscopic cholecystectomy versus when they did not (median: 28.5 versus 19.25; $P = .042$). Lee and colleagues[34] found that some operative assessment tool scores (mean ± standard deviation) significantly improved when trainee surgeons completed a warm-up before performing laparoscopic renal surgery (mobilization of the colon [MC]: 21.43 ± 0.54 versus 19.86 ± 0.51, $P = .04$) but not all did (intracorporeal suturing and knot tying [ISKT]: 3.50 ± 0.23 versus 3.54 ± 0.25, $P = .92$). Lee and colleagues also compared procedural times for trainee surgeons completing real cases with and without a warm-up. They found no differences between groups in the mean time (minutes) required for both MC (26.6 versus 29.4, $P = .40$) and ISKT (7.6 versus 5.8, $P = .17$). Other objective measures of cognitive and psychomotor performance (attention, distraction, workload, spatial reasoning, movement

Table 1

Characteristics of Seven Studies Included in an Advanced Literature Review of the Effects of Rehearsal and Warm-up on Clinical Performance, 2012

First author	Study design	Setting	Technology	No. of patients	Intervention type	Experience of operators (no. of operators/procedures)
Cates[8]	Case report	Carotid artery stenting	VR simulator	1	Rehearsal	Not specified
Hislop[29]	Case series	Carotid artery stenting	VR simulator	5	Rehearsal	3 with mean (range) of 51 (13–80)
Roguin[30]	Case report	Carotid artery stenting	VR simulator	1	Rehearsal	Not specified
Calatayud[31]	RCT	Laparoscopic cholecystectomy	VR simulator	20	Warm-up	5 with > 100; 5 with < 40
Willaert[32]	Case report	Carotid artery stenting	VR simulator	1	Rehearsal	Not specified
Lee[34]	RCT	Laparoscopic renal surgery	VR simulator; laparoscopic pelvic box trainer	28	Warm-up	2 with < 5; 2 with 5–20; 3 with > 20
Willaert[33]	Case series	Carotid artery stenting	VR simulator	15	Rehearsal	3 with > 50

Abbreviations: RCT indicates randomized controlled trial; VR, virtual reality.

Table 2
Quality of Five Observational Studies Included in an Advanced Literature Review of the Effects of Rehearsal on Clinical Performance, 2012

First author	Selection	Comparability	Outcomes
Cates[8]	No description of patient or operator recruitment.	The patient served as his or her own comparator.	Technical and nontechnical outcomes used self-report and secure records.
Hislop[29]	No description of patient recruitment. Operators were a select group, somewhat representative of average.	Each patient served as his or her own comparator.	Technical and nontechnical outcomes used both self-report and secure records, without follow-up.
Roguin[30]	No description of patient or operator recruitment.	The patient served as his or her own comparator, except for fluoroscopy time and volume of contrast for which the institutional average was used as the comparator.	Technical outcomes used self-report, without follow-up.
Willaert[32]	Unclear. The patient was selected based on favorable anatomy.	The patient served as his or her own comparator.	Technical and nontechnical outcomes used both self-report and secure records, without follow-up.
Willaert[33]	All patients suitable for the intervention were considered eligible, and exclusions were based on quality of CT imaging. No description of operator recruitment.	Each patient served as his or her own comparator.	Technical and nontechnical outcomes used both self-report and independent structured assessment, without follow-up.

Note: The authors assessed methodological quality using the Newcastle–Ottawa Quality Assessment Scale[16]; no observational studies assessed the effects of warm-up on clinical performance.

smoothness, posture stability) also significantly improved when a warm-up was performed.[34]

Technical outcomes: Endovascular surgery. Carotid artery stenting procedures were used for all endovascular rehearsals. We found limited comparative outcomes data from these case reports and series. To compare surgeons' overall technical performance in both rehearsal and real cases, Willaert and colleagues[33] used the Procedure Specific Rating Scale (PSRS) and the Global Rating Scale (GRS); they found no difference in the quality of the performances in either setting (PSRS: 24 versus 26, $P = .498$; GRS: 34 versus 33, $P = .979$). None of the included studies of rehearsal before carotid artery stenting objectively evaluated the effect of rehearsal on technical outcomes in real cases. These case studies did indicate a correlation between rehearsal and real cases in regard to choice of endovascular devices but not for procedural times or volume of contrast.[8,29,30,32,33]

Nontechnical outcomes. Nontechnical outcomes were reported inconsistently across the included studies (see Table 4).

Assessment of publication biases

Because of the small number of included articles, we did not assess publication bias. We found no evidence of funding bias—Calatayud and colleagues[31] did not include a declaration of funding or conflicts of interest, all other authors declared no conflicts of interest. Finally, we found no evidence of multiple publications of the included study data in our literature search.

Discussion

Our review demonstrates that rehearsal and warm-up by operators and operating teams performing endovascular and laparoscopic surgeries is feasible. According to two studies, warm-up prior to laparoscopic cholecystectomy and renal surgery improved the technical performance of the operators.[31,34] Still, objective evidence of the effects of rehearsal and warm-up on both technical and nontechnical outcomes remains limited.

Simulation is a well-established method for learning and maintaining technical skills in health care,[5] but preoperative rehearsal and warm-up are newer concepts. In 2007, Cates and colleagues[8] reported on patient-specific rehearsal. Since then, however, only six studies have reported on preoperative rehearsal or warm-up in clinical settings.[29–34]

Table 3
Quality of Two Randomized Controlled Trials Included in an Advanced Literature Review of the Effects of Warm-up on Clinical Performance, 2012

First author	Randomization	Concealment of allocation	Blinding	Handling of withdrawals and losses
Calatayud[31]	Unclear. Operators were randomized, not patients.	Low risk. Closed envelope technique.	Unclear. To intervention: yes. Outcomes analyses: unclear.	Not analyzed by intention-to-treat.
Lee[34]	Unclear. Operators were randomized, not patients.	Unclear.	Unclear. Assessors were blinded, but not possible to blind participants.	No losses or withdrawals.

Note: The authors graded the risk of bias as high risk, low risk, or unclear; no randomized controlled trials assessed the effects of rehearsal on clinical performance.

Table 4

Effects of Interventions on Nontechnical Outcomes in an Advanced Literature Review of the Effects of Rehearsal and Warm-up on Clinical Performance, 2012

First author	Face validity	Content validity	Patient outcomes	Other outcomes
Cates[8]	Catheter movement and handling, catheter–catheter interaction, wire movement and dynamics, and embolic protective device deployment and retrieval were similar to the real case.	N/A	No complications in the immediate postoperative period, and the patient was asymptomatic at one year.	N/A
Hislop[29]	Operators strongly agreed that imaging, instruments, tactile feedback, and physiologic feedback were realistic.	N/A	N/A	High level of satisfaction
Willaert[32]	Simulator was considered realistic by the operator.	N/A	N/A	Team satisfaction: Increased operative flow and patient safety. Confidence: Improved confidence in respective team roles. Communication: Improved among team members.
Willaert[33]	Simulator was considered realistic by members of the intervention team.	For 5 of 15 patients, the simulator did not resemble the real catheterization of the common carotid artery. For 4 of 15 patients, the simulator did not predict difficulty in cannulation of the stenotic internal carotid artery lesion.	No perioperative strokes, myocardial infarctions, or deaths occurred.	Team satisfaction: Overall, the simulation was rated highly by team members. Confidence: More effective at enhancing confidence for inexperienced anesthetists. Communication: No significant difference between rehearsal and real intervention for all categories of NOTECHS and MHPTS.

Note: Roguin and Beyar,[30] Calatayud and colleagues,[31] and Lee and colleagues[34] did not evaluate nontechnical outcomes.
Abbreviations: N/A indicates not applicable; NOTECHS, Non-Technical Skills for Surgeons rating scale; MHPTS, Mayo High Performance Teamwork Scale.

Preclinical research supports the theory that rehearsal and warm-up will improve the performance of operating teams and thus patient safety.[9] In preclinical studies, for example, short periods (10–30 minutes) of mental practice,[19] simple surgical exercises,[23] and laparoscopic warm-up[21] each have been shown to improve operator performance. Synthesis of the results of clinical studies is more difficult, however, because of the diversity of the outcomes measured and a lack of RCTs to evaluate the effects of the interventions. The findings from the RCTs by Lee and colleagues[34] and Calatayud and colleagues[31] indicate that individual task and overall technical performance for laparoscopic surgery can be improved by warm-up. However, the evidence for patient-specific rehearsal using virtual reality simulation prior to endovascular procedures, although encouraging, is more limited. Combined, these findings raise more questions than they answer about the implications of such practices for operators performing complex clinical procedures and about the optimal application of these findings to clinical practice.

Do rehearsal and warm-up have a similar effect on the performance of novice, competent, and expert operators? In sports, athletes with more experience require less time to warm up than rookie athletes, suggesting that relearning is faster than initial learning.[35] Kahol and colleagues[23] found that warm-up by surgical residents reduced errors regardless of the operator's experience, but the amount of the reduction in errors did not correlate with the level of experience. This finding may indicate that the clinical practice warm-up may be beneficial for operators at all levels of experience, but we do not know which operators will benefit most from warm-up. Importantly, when measuring the effect of rehearsal or warm-up, the operator's experience with simulation also must be considered as we know a learning curve exists for simulator platforms.[36]

In health care, likely most operators will benefit from rehearsal or warm-up,[23] but the optimal timing and length of any exercises for operators of differing levels of expertise and experience are not known. In both preclinical and clinical studies, investigators found that 15 minutes of warm-up was sufficient to improve subsequent technical performance.[23,31] However, the minimum and optimal length of time of preprocedural warm-up in these studies were not investigated.

Human errors in the operating room rarely are due to deficiencies in technical performance alone but often are related to underlying systems failures and nontechnical errors by the operating team.[37] Increasingly, investigators have recognized that improving the performance of the operating team is complex and that interactions between team members are significant and can influence the overall team performance and possibly patient outcomes.[12,38,39] Whereas warm-up may

improve the performance of the individual, rehearsal as a team may have a greater impact. For example, in separate cases presented by Hislop and colleagues[29] and Willaert and colleagues,[32,33] team performance improved with patient-specific rehearsal within 24 hours of the real case. However, other studies did not consider these outcomes.[8,30,31,34] Future studies of rehearsal and warm-up should assess objective measures of team nontechnical performance, including team alignment, trust, engagement, and workflow.[3,40]

The rationale for rehearsal and warm-up is derived largely from other highly skilled domains, such as sports, music, and aviation. Hence, rehearsal and warm-up in medicine should be subject to the same limitations as these non-health-care domains. Similar to athletes after warming up, operators in health care likely will experience warm-up decrement, in which the effects of the warm-up will decrease in the time between warm-up and performance.[11] This decrement may affect the retention of technical skills, manual dexterity, and mental preparation but has not been evaluated in studies of simulated medical procedures. Similarly, negative transfer also may have an impact on the effect of warm-up and rehearsal.[10] Negative transfer occurs when a new behavior has a negative effect on learned behavior and may occur in the time between rehearsal or warm-up and performance.

In clinical practice, several limitations exist to providing the resources necessary for rehearsal or warm-up, including the availability of faculty, simulation platforms, time limitations, and cost constraints. The ability to warm up before a procedure will be tempered by the demands of a busy operating room or procedural suite. A more efficient alternative may be mental practice. Some have suggested that mental practice has a similar overall effect to warm-up, and Arora and colleagues[19] demonstrated that it improves the overall performance of operators practicing simulated laparoscopic cholecystectomies. However, although mental practice requires fewer resources than simulation, it may be more time consuming for operators, and the implications for operating room efficiency are not known.

Our review has some limitations. Our decision to include observational studies was made a priori with the knowledge that few randomized trials have been conducted in this field. Furthermore, as a result of the heterogeneity of study designs and of outcomes, a meta-analysis was not possible. These factors negatively affected our ability to perform a high-quality systematic review, and consequently our results may be subject to bias and our interpretation of the data must be cautious. Our review also may have been influenced by publication bias, despite our efforts to identify unpublished and negative studies.[41]

In conclusion, we still do not know the effect of rehearsal or warm-up prior to performing clinical procedures on patient safety. Current evidence from clinical research of rehearsal and warm-up are very limited. These preliminary studies suggest that the performance of operators and/or operating teams can be improved by rehearsal and warm-up. However, a paucity of objective evidence and comparative research in the literature supports their routine use.

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References

1 Manser T. Teamwork and patient safety in dynamic domains of healthcare: A review of the literature. Acta Anaesthesiol Scand. 2009;53:143–151.
2 Kaufman DR, Patel VL. Expertise in the clinical interview: A cognitive analysis. Res Med Educ. 1988;27:167–172.
3 Baker DP, Salas E, King H, Battles J, Barach P. The role of teamwork in the professional education of physicians: Current status and assessment recommendations. Jt Comm J Qual Patient Saf. 2005;31:185–202.
4 Satava RM. Virtual reality surgical simulator. The first steps. Surg Endosc. 1993;7:203–205.
5 Cook DA, Hatala R, Brydges R, et al. Technology-enhanced simulation for health professions education: A systematic review and meta-analysis. JAMA. 2011;306:978–988.
6 Sturm LP, Windsor JA, Cosman PH, Cregan P, Hewett PJ, Maddern GJ. A systematic review of skills transfer after surgical simulation training. Ann Surg. 2008;248:166–179.
7 McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. Acad Med. 2011;86:706–711.
8 Cates CU, Patel AD, Nicholson WJ. Use of virtual reality simulation for mission rehearsal for carotid stenting. JAMA. 2007;297:265–266.
9 Harnett MJ, Shorten GD. Address rehearsal. Eur J Anaesthesiol. 2011;28:675–677.
10 Schmidt RA, Lee TD. Motor Control and Learning: A Behavioral Emphasis. 5th ed. Champaign, Ill: Human Kinetics; 2011.
11 Ajemian R, D'Ausilio A, Moorman H, Bizzi E. Why professional athletes need a prolonged period of warm-up and other peculiarities of human motor learning. J Mot Behav. 2010;42:381–388.
12 Satava RM, Hunter AM. The surgical ensemble: Choreography as a simulation and training tool. Surg Endosc. 2011;25:3080–3086.
13 Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. J Clin Epidemiol. 2009;62:1006–1012.
14 Stroup DF, Berlin JA, Morton SC, et al. Meta-analysis of observational studies in epidemiology: A proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA. 2000;283:2008–2012.
15 Cochrane Consumers and Communication Review Group. Author resources. http://cccrg.cochrane.org/author-resources. Accessed April 30, 2014.
16 Wells GA, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomized studies in meta-analyses. http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp. Accessed April 30, 2014.
17 Crochet P, Aggarwal R, Dubb SS, et al. Deliberate practice on a virtual reality laparoscopic simulator enhances the quality of surgical technical skills. Ann Surg. 2011;253:1216–1222.
18 Plerhoples TA, Zak Y, Hernandez-Boussard T, Lau J. Another use of the mobile device: Warm-up for laparoscopic surgery. J Surg Res. 2011;170:185–188.
19 Arora S, Aggarwal R, Sirimanna P, et al. Mental practice enhances surgical technical skills: A randomized controlled study. Ann Surg. 2011;253:265–270.
20 Willaert WI, Aggarwal R, Van Herzeele I, et al; European Virtual Reality Endovascular Research Team EVEResT. Patient-specific endovascular simulation influences interventionalists performing carotid artery stenting procedures. Eur J Vasc Endovasc Surg. 2011;41:492–500.
21 Do AT, Cabbad MF, Kerr A, Serur E, Robertazzi RR, Stankovic MR. A warm-up laparoscopic exercise improves the subsequent laparoscopic performance of

ob-gyn residents: A low-cost laparoscopic trainer. JSLS. 2006;10:297–301.
22 Willaert W, Aggarwal R, Harvey K, et al; European Virtual Reality Endovascular Research Team (EVEResT). Efficient implementation of patient-specific simulated rehearsal for the carotid artery stenting procedure: Part-task rehearsal. Eur J Vasc Endovasc Surg. 2011;42:158–166.
23 Kahol K, Satava RM, Ferrara J, Smith ML. Effect of short-term pretrial practice on surgical proficiency in simulated environments: A randomized trial of the "preoperative warm-up" effect. J Am Coll Surg. 2009;208:255–268.
24 Hislop SJ, Hsu JH, Narins CR, et al. Simulator assessment of innate endovascular aptitude versus empirically correct performance. J Vasc Surg. 2006;43:47–55.
25 Arora S, Aggarwal R, Sevdalis N, et al. Development and validation of mental practice as a training strategy for laparoscopic surgery. Surg Endosc. 2010;24:179–187.
26 Wong GK, Zhu CX, Ahuja AT, Poon WS. Stereoscopic virtual reality simulation for microsurgical excision of cerebral arteriovenous malformation: Case illustrations. Surg Neurol. 2009;72:69–72.
27 Soler L, Marescaux J. Patient-specific surgical simulation. World J Surg. 2008;32:208–212.
28 Forest C, Comas O, Vaysière C, Soler L, Marescaux J. Ultrasound and needle insertion simulators built on real patient-based data. Stud Health Technol Inform. 2007;125:136–139.
29 Hislop SJ, Hedrick JH, Singh MJ, et al. Simulation case rehearsals for carotid artery stenting. Eur J Vasc Endovasc Surg. 2009;38:750–754.
30 Roguin A, Beyar R. Real case virtual reality training prior to carotid artery stenting. Catheter Cardiovasc Interv. 2010;75:279–282.
31 Calatayud D, Arora S, Aggarwal R, et al. Warm-up in a virtual reality environment improves performance in the operating room. Ann Surg. 2010;251:1181–1185.
32 Willaert W, Aggarwal R, Bicknell C, et al; European Virtual Reality Endovascular Research Team (EVEResT). Patient-specific simulation in carotid artery stenting. J Vasc Surg. 2010;52:1700–1705.
33 Willaert WI, Aggarwal R, Van Herzeele I, et al. Role of patient-specific virtual reality rehearsal in carotid artery stenting. Br J Surg. 2012;99:1304–1313.
34 Lee JY, Mucksavage P, Kerbl DC, et al. Laparoscopic warm-up exercises improve performance of senior-level trainees during laparoscopic renal surgery. J Endourol. 2012;26:545–550.
35 Ericsson KA. The Cambridge Handbook of Expertise and Expert Performance. New York, NY: Cambridge University Press; 2006.
36 Patel AD, Gallagher AG, Nicholson WJ, Cates CU. Learning curves and reliability measures for virtual reality simulation in the performance assessment of carotid angiography. J Am Coll Cardiol. 2006;47:1796–1802.
37 Yule S, Flin R, Paterson-Brown S, Maran N. Non-technical skills for surgeons in the operating room: A review of the literature. Surgery. 2006;139:140–149.
38 Salas E, DiazGranados D, Klein C, et al. Does team training improve team performance? A meta-analysis. Hum Factors. 2008;50:903–933.
39 Schraagen JM, Schouten T, Smit M, et al. Assessing and improving teamwork in cardiac surgery. Qual Saf Health Care. 2010;19:e29.
40 Entin EB, Lai F, Barach P. Training teams for the perioperative environment: A research agenda. Surg Innov. 2006;13:170–178.
41 Dickersin K. The existence of publication bias and risk factors for its occurrence. JAMA. 1990;263:1385–1389.