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REVIEW

Gender differences in the acquisition of surgical skills: a systematic review

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Abstract
Background Females are less attracted than males to surgical specialties, which may be due to differences in the acquisition of skills. The aim of this study was to systematically review studies that investigate gender differences in the acquisition of surgical skills.
Methods We performed a comprehensive database search using relevant search phrases and MeSH terms. We included studies that investigated the role of gender in the acquisition of surgical skills.
Results Our search yielded 247 studies, 18 of which were found to be eligible and were therefore included. These studies included a total of 2,106 study participants. The studies were qualitatively synthesized in five categories (studies on medical students, studies on both medical students and residents, studies on residents, studies on gender differences in needed physical strength, and studies on other gender-related training conditions). Male medical students tended to outperform females, while no gender differences were found among residents. Gaming experience and interest in surgery correlated with better acquisition of surgical skills, regardless of gender. Although initial levels of surgical abilities seemed lower among females, one-on-one training and instructor feedback worked better on females and were able to help the acquisition of surgical skills at a level that negated measurable gender differences. Female physicians possess the required physical strength for surgical procedures, but may face gender-related challenges in daily clinical practice.
Conclusion Medical students are a heterogeneous group with a range of interests and experiences, while surgical residents are more homogeneous perhaps due to selection bias. Gender-related differences are more pronounced among medical students. Future surgical curricula should consider tailoring personalized programs that accommodate more mentoring and one-on-one training for female physicians while giving male physicians more practice opportunities in order to increase the output of surgical training and acquisition of surgical skills.

Keywords Gender differences · Surgery · Surgical skills · Surgical career · Surgical simulation · Medical education

Medicine used to be a predominantly male occupation, but an increasing influx of females into medical schools is changing the future demographics of physicians [1, 2]. Today, females account for half of all medical students in the USA [2] and are in the majority in several European countries [3]. This demographic shift influences specialty preferences. Females tend to be less attracted to surgical specialties [1, 2, 4], which could lead to staff shortages among surgical specialties [4].

Genetic, hormonal, and environmental differences between males and females manifest in a complex manner. For example, although anatomical studies suggest gender differences in the brain [5, 6], the functional value of these

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Table 1 Search terms and the number of studies identified

Search no.	Search entry	Results
1	("Sex Factors"[Mesh]) AND "Surgical Procedures, Operative/education"[Mesh]	36
2	(("Sex Factors"[Mesh]) AND "Surgical Procedures, Operative"[Mesh]) AND "Surgical Procedures, Minimally Invasive/education"[Mesh]	12
3	(("Sex Factors"[Mesh]) AND "Surgical Procedures, Operative"[Mesh]) AND "Clinical Competence"[Mesh]	92
4	"Sex factors"[Mesh] AND "Laparoscopy"[Mesh] AND "Clinical Competence"[Mesh]	16
5	"Laparoscopy/Education"[Mesh] AND "Spatial Behavior"[Mesh]	2
6	(((("Surgical Procedures, Operative"[Mesh]) AND "Clinical Competence"[Mesh]) AND "Female"[Mesh]) AND "Male"[Mesh]) AND "Sex"	89
Total number of publications, duplicates included		247

differences is unclear [6–10]. Psychomotor studies have found gender differences in solving practical tasks [11]. Visuospatial gender differences exist [12, 13], and there is even evidence to suggest a gender-specific difference in the interaction between psychomotor learning and hormonal response [14, 15]. Understanding the different ways in which people learn is crucial in order to better design the surgical education of future that accommodates the educational needs of both genders.

The aim of this study was to systematically review studies that investigate gender differences in the acquisition of surgical skills among medical professionals.

Materials and methods

We followed the PRISMA guidelines for reporting systematic reviews [16].

Eligibility criteria

We included studies that investigated the role of gender in the acquisition of surgical skills. All types of published journal articles were included (randomized controlled trials, non-randomized comparative studies, case–control studies, cohort studies, multicenter studies, descriptive studies, evaluation studies, retrospective studies, clinical trials, and other journal articles). We excluded studies that only stated the presence or lack of gender differences without any further specifications. We excluded abstracts with no articles and studies in languages other than English and Danish.

Search strategy and study selection

We searched the PubMed database using relevant search terms and Medical Search Headings and Subheadings (MeSH) combined with Boolean operators (Table 1). We compiled the search on the April 26, 2014. Two authors (AA and LK) independently performed the searches and selected relevant articles that met the eligibility criteria. Differences were solved through discussion until a consensus was achieved. The reference lists of all included studies were examined for additional studies that met our eligibility criteria.

Data collection and synthesis of results

We extracted data on the year of publication, country of origin, study design, study population characteristics including employment and gender distribution, means of testing, and study results. Due to the heterogeneity of the study questions, we were unable to perform any meaningful meta-analysis. All authors (AA, YS, CR, and LK) contributed to the qualitative synthesis of the results.

Results

Our electronic search identified 247 publications (Table 1; Fig. 1), of which 14 remained after removing duplicates and obviously irrelevant articles. All 14 publications were reviewed in full-text format. Using the reference lists, we identified five additional publications of interest. From the total 19 publications that were reviewed in full text, one was excluded due to our eligibility criteria. A total of 18 studies were included in our qualitative synthesis with a total of 2,106 study participants (Table 2).

The included studies were comprised of nine cohort studies (eight experimental and one observational), five cross-sectional studies (three experimental and two observational), two randomized controlled studies, one randomized controlled cross-over study and one non-randomized controlled study. The gender distribution ranged from 11 to 61 % females, and one study did not report the gender distribution. Nine studies were from the USA, two from Canada, two from the UK, two from Denmark, two from Sweden, and one from Switzerland. Fourteen studies used simulated surgery, two were based on self-reported information on surgery, one relied on Medical College Admission Test

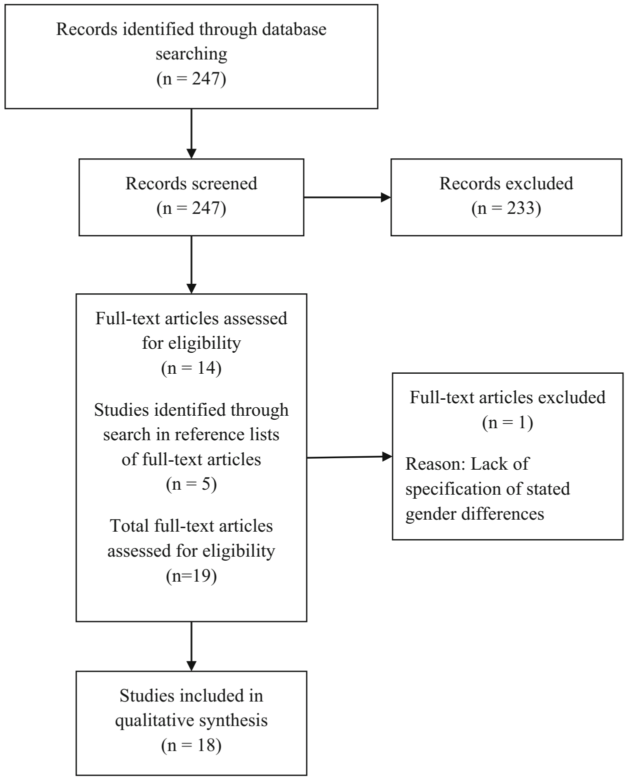

Fig. 1 Flow chart of the study selection process

(MCAT) results and psychometric tests, and one study used an isometric strength testing unit. The authors agreed to present the studies using five categories based on the study population in order to systematize the presentation of the studies and present the tendencies that generally correlated within the chosen study subjects:

- Medical students [17–24].
- Both medical students and residents [25–27].
- Residents only [28–30].
- Gender differences in needed physical strength [31, 32].
- Other gender-related training conditions [33, 34].

Studies on medical students

Studies on medical students were based on simulated laparoscopy and virtual reality (VR) simulators (Table 3). Two of the studies focused on gender-specific anatomical and psychological predispositions [17, 18]. Visuospatial ability correlated with performance on a VR simulator among right-handed males, but not among females [18]. In another study with a laparoscopic simulation setting, males showed a higher degree of ambidexterity and higher precision using their dominant hand; this is suggested to be due to the standard sizes of the instruments, which may not have been designed for smaller hands among females [17]. Other studies have looked into the students' fields of interest. For example, males generally perform better on VR simulators [18–20], but scores also correlate with gaming experience, regardless of gender [18, 19]. Simulator performance is also correlated with students' preference of surgery as their future specialty, regardless of gender [20, 21]. Even when adjusting for factors such as gaming and preference for surgery, which may differ demographically between the genders, males seems to have a significant advantage [18, 19, 21].

Other studies focused on the skills learning environment [22–24]. The performances of female medical students correlated with their theoretical knowledge, which is not the case for males [22]. When learning suturing, males showed a preference for repeated practice, while females preferred one-on-one instruction [23]. Instructor feedback versus no instructor feedback in VR simulator training demonstrated an interesting gender-specific difference in impact: without instructor feedback, males outperform females, whereas females and males performed equally with instructor feedback [24]—this indicates that females respond better to instructor feedback [24].

In summary, male medical students outperform female medical students, partly due to gender-specific interests, such as gaming and preference for surgery. Studies also suggest that observed differences could be due to gender-related differences in learning preferences.

Studies on both medical students and residents

Three studies included both medical students and residents (Table 4). On VR simulators, males tend to outperform females [25, 26]. Interestingly, gender differences cease to exist if gaming is included as a factor in subgroup analyses [26]. Another study compared initial and final completion time of Fundamentals of Laparoscopic Surgery tasks [27]. Initially, males received higher performance scores, but females responded better than males to training and gender differences eventually disappeared [27]. Thus, consistent with previously mentioned studies on medical students, studies on both medical students and residents have also found an effect of gaming experience and learning environment.

Studies on residents only

Three studies included residents only (Table 5). One study found that female residents outperformed male residents in academic achievements measured on MCAT, National Board Examinations, and verbal tests. Males, on the other hand, achieved higher scores on visuoperceptive skills and on confidence and task organization [28]. On a VR-simulated laparoscopy, male residents completed tasks faster than females, but the number of errors and unnecessary

Table 2 Characteristics of included studies

References	Year	Country	Design	Population	Gender distribution (males/females) (%)	Means of testing
[17]	2007	Scotland	Randomized controlled cross-over study	MS ($n = 52$)	(62/38)	Simulation surgery
[18]	2004	Sweden	Experimental cross-sectional study	MS ($n = 17$)	(82/18)	Visuospatial test Simulation surgery
[19]	2007	USA	Non-randomized controlled experimental study	MS ($n = 51$)	(39/61)	Simulation surgery
[20]	2011	USA	Experimental cross-sectional study	MS ($n = 32$)	(50/50)	Preliminary survey Simulation surgery
[21]	2010	Canada	Experimental cohort study	MS ($n = 32$)	(59/41)	Demographic data survey Simulation surgery
[22]	2013	Sweden	Experimental cohort study	MS ($n = 158$)	(53/47)	Simulation surgery
[23]	2005	Canada	Randomized controlled study	MS ($n = 42$)	(50/50)	Cognitive imaging Simulated surgery
[24]	2013	Denmark	Randomized controlled study	MS ($n = 91$)	(43/57)	Simulation surgery
[25]	2006	Switzerland	Experimental cohort study	MS + R ($n = 20$)	(60/40)	Standardized questionnaire Simulation surgery
[26]	2007	USA	Experimental cohort study	MS + R ($n = 26$)	(65/35)	Demographic data survey Simulation surgery
[27]	2012	USA	Experimental cohort study	MS + R ($n = 132$)	(60/40)	Simulation surgery
[28]	1985	USA	Observational cross-sectional study	R ($n = 118$)	(89/11)	MCAT results Psychometric tests Surgical tests
[29]	2003	Denmark	Experimental cohort study	R ($n = 25$)	(72/28)	Simulation surgery
[30]	2008	USA	Experimental cohort study	R ($n = 46$)	(59/41)	Simulation surgery
[31]	2005	USA	Experimental cross-sectional study	R ($n = 55$)	(69/31)	Isometric strength testing unit
[32]	2009	USA	Experimental cohort study	MS + R ($n = 65$)	(52/48)	Force transducing laryngoscopy
[33]	2000	USA	Observational cohort study	R ($n = 830$)	N/A	Number of surgical procedures during residency
[34]	2005	UK	Observational cross-sectional study	R ($n = 314$)	(63/37)	Questionnaires

MS medical students, *R* residents

movements were similar [29]. On a box training laparoscopy simulator, no gender differences were found, and after a 4-week skill training program, one study was initially unable to find any gender differences [30]. After a year, however, retention was significantly higher among females [30]. Results at resident level are more mixed and do not show any clear gender differences.

Studies on gender differences in required physical strength

Two studies investigated the amount of strength required to perform procedures (Table 6). A study on obstetric forceps delivery showed that although male residents are able to generate more force than female residents, the differences are above any clinically meaningful level and are therefore insignificant for clinical practice [31]. Similarly, a study on intubation found that females do not lack the necessary physical strength and found no significant gender differences [32].

Studies on other gender-related training conditions

Two studies explored gender-related behavior (Table 7). A study on obstetrics residency review forms in the USA found that male residents had higher forceps delivery rates

Table 3 Studies on medical students

References	Year	Design	Sample size	Gender distribution (males/females) (%)	Means of testing	Results
Studies indicating gender differences						
[17]	2007	Randomized controlled cross-over study	52	(62/38)	LapSim Basic Skills, unilateral and bilateral task	Right-handed males exhibit greater level of ambidexterity and have a shorter execution time in bimanual and unilateral tasks.
[20]	2011	Experimental cross-sectional study	32	(50/50)	Minimally Invasive Surgical Trainer-Virtual Reality (Transfer-Place)	Males performed better than females on the VR simulator in multivariate models
[22]	2013	Experimental cohort study	158	(53/47)	URO Mentor endourological simulator	Males had faster simulator completion time
					Results of a written exam in basic surgery	Theoretical test results correlated with surgical performance in females, but not in males
[23]	2005	Randomized controlled study	42	(50/50)	Cognitive imaging	Males performed better on visual-spatial representation
					Simulated laparoscopy (suturing)	Females preferred one-on-one instruction
[24]	2013	Randomized controlled study	91	(43/57)	LapSim, right-sided laparoscopic salpingectomy	Males reached expert level faster than women
						More pronounced effect of instructor feedback in females
Studies with mixed results						
[19]	2007	Non-randomized controlled experimental study	52	(39/61)	Minimally Invasive Surgical Trainer-Virtual Reality (Acquire-Place)	Males performed significantly better on the VR simulator
					Training on a box trainer	No gender differences on the box trainer
Studies indicating no gender differences						
[18]	2004	Experimental cross-sectional study	17	(82/18)	Visuospatial test	No gender-specific difference in VR scores
					Minimally Invasive Surgical Trainer-Virtual Reality (Acquire-Place)	Correlation between visuospatial scores and VR scores in males.
[21]	2010	Experimental cohort study	32	(59/41)	Demographic data survey	No gender differences in laparoscopy learning, or the learning curve
					Fundamentals of Laparoscopic Surgery training	Better performance among participants with a interest in surgical specialty

VR virtual reality

Table 4 Studies on both medical students and residents

References	Year	Design	Sample size	Gender distribution (males/females) (%)	Means of testing	Results
[25]	2006	Experimental cohort study	20 MS: 80 % R: 20 %	(60/40)	Standardized questionnaire Xitact LS500 Simulator (clip-and-cut task)	Weak tendency (although not statistically significant) toward better performance among males
[26]	2007	Experimental cohort study	26 MS: 42 % R: 58 %	(65/35)	Demographic data survey Minimally Invasive Surgical Trainer-Virtual Reality (Acquire-Place and Traversal)	Females were slower in VR tasks Non-gamers females were significantly slower to proficiency in VR tasks Gamer females and gamer males were equally good at VR tasks
[27]	2012	Experimental cohort study	132 MS: 88 % R: 12 %	(60/40)	Fundamentals of Laparoscopic Surgery training (peg transfer, circle cut, extracorporeal knot tying, and intracorporeal knot tying)	Initial lower performance among females No difference in performance after training Training increases females' performance more than it increases males' performance

MS medical students, *R* residents, *VR* virtual reality

Table 5 Studies on residents only

References	Year	Design	Sample size	Gender distribution (males/females) (%)	Means of testing	Results
[28]	1985	Observational cross-sectional study	118	(89/11)	Medical College Admission Test (MCAT) results Psychometric tests 12-item Surgical Skills Rating Scale	Females received higher scores in academic tests and visual patterns Males received higher surgical skills ratings
[29]	2003	Experimental cohort study	25	(72/28)	Minimally Invasive Surgical Trainer-Virtual Reality	Males completed the tasks faster than females No gender differences between the number of errors or unnecessary movements
[30]	2008	Experimental cohort study	46	(59/41)	Laparoscopic box trainer using the Inanimate System for Training and Evaluation of Laparoscopic Skills	Gender did not correlate with initial or post-training performance Females demonstrated better skills retention Significant better performance among participants in a general surgery training program

Table 6 Studies on gender differences in needed physical strength

References	Year	Design	Sample size	Gender distribution (males/females) (%)	Means of testing	Results
[31]	2005	Experimental cross-sectional study	55 OB/GYN residents	(69/31)	Isometric strength testing unit	Male residents are able to recruit higher pull force than their female counterparts Both genders are able to generate force ranges that are relevant and optimal for clinical purposes
[32]	2009	Experimental cohort study	65 anesthesiologist and medical students	(52/48)	Force transducing laryngoscope Manikin	No gender differences in the ability of intubation

Table 7 Studies on other gender-related training conditions

References	Year	Design	Sample size	Gender distribution (males/females) (%)	Means of testing	Results
[33]	2000	Observational cohort study	830 OB/GYN residents	N/A	Number of surgical procedures during residency	Males had higher rate of forceps—and operative vaginal deliveries
[34]	2005	Observational cross-sectional study	314 residents in ophthalmology	(63/37)	Questionnaires on residents' surgical experience	Males more likely to have access to surgical training facilities Females completed fewer surgeries per week and overall

[33]. Another study investigated the influence of demographic factors on cataract surgery training and found that females were less likely to access surgical training facilities [34]. After surgical training, females operated fewer patients per week and had a lower overall number of surgeries [34].

Discussion

The findings of our systematic review suggest the need to realize that males and females are not alike when it comes to acquisition of surgical skills. Male and female medical students differ in their visuospatial abilities, interest in surgery, and gaming experience [18–21]. Providing females with instructor feedback and one-to-one training seem to eliminate these differences [23, 24, 27, 30]. We also found that there are no meaningful differences in the level of strength required for surgery [31, 32], but there do seem to be gender-specific differences in surgical work practice [33, 34].

Male medical students are initially more confident about their surgical abilities and take more risks [18, 28, 35, 36]. Female medical students tend to have longer reaction time with higher precision [11, 23, 37, 38], which can be described as risk-averse behavior. This may explain why males perform better initially. This perception of males being risk-takers and females being risk-averse seems consistent within a wide range of behavioral studies, ranging from motor vehicle collisions to financial investments [39].

In the acquisition of surgical skills, male medical students performed better and studies found the greatest gender differences in the visuospatial abilities and speed [20, 22, 23]. Similar observations on visuospatial differences were also found in other psychomotor studies outside of the medical profession [12, 13] and suggest a brain dimorphism on a general population level. There may also be a cultural influence, as males may be more likely to have played video and ball games during their childhood, which could help develop their visuospatial abilities. Cross-cultural studies on this matter are warranted.

Studies on residents showed mixed results, and female residents even outperformed males in retention tests [29, 30]. This may be due to a selection process into surgical specialties. Physicians accepted into resident programs may be more homogeneous in areas such as interest and gaming experience, which may explain the less clear differences in resident-only studies.

Female residents and medical students acquire surgical skills markedly better when trained appropriately [23, 27, 30], which includes one-on-one training with clear instructor feedback [23, 24]. Therefore, a key message from this systematic review is that surgical training of females should include more supervision.

Female physicians are less likely to perform surgical interventions in clinical practice than males [33, 34]. We have no reason to believe that this is due to a lack of strength [31, 32]. Instead, studies suggest that female physicians may be discriminated against during surgical rotations [40]. Firstly, this is unacceptable for purely ethical reasons. Secondly, considering the higher rate of female medical students [4], this will naturally lead to staff shortages in the surgical specialties unless such discrimination is addressed. Mentoring initiatives are currently being implemented as a way of attracting a higher number of female colleagues [41].

A systematic review is only as good as the included studies, and the consequent limitations of this study should be noted. The number of studies is low, most of the studies have small sample sizes, and the diversity of their design does not permit a quantitative comparison of outcomes. Previous life experience may have an influence on surgical abilities; for example, several studies have highlighted the value of gaming experience. We suggest that future studies should investigate the influence of other experiences that have not been highlighted. All but one of the studies is based on simulated surgery, which does not represent the true diversity of the surgical world. Even though simulators provide a great tool for repeatable comparison, the abundant number of variables that prevails in reality is overlooked, which leads to an oversimplified amount of evidence to explain what is a complex topic. Finally, all studies were conducted in Western countries, which may not represent the realities in the rest of the world.

In conclusion, male medical students seem to outperform female medical students, which may be due to differences in their visuospatial abilities and their varying interests that are associated with better acquisition of surgical skills. This initial difference disappears early in a surgical career, probably due to a selection bias. While males are more willing to practice on their own and take the associated risks, females prefer mentorship and one-on-one instructor feedback. Most importantly, surgical training eliminated initial gender differences. Therefore, we recommend personalized surgical training programs that acknowledge the different needs of participants, such as mentorship and one-on-one training. Gender issues should be considered when designing surgical training and curricula to better accommodate the needs of future surgeons.

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