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The ergonomic impact of robotic vs. laparoscopic surgery on operating room nurses: A multicenter survey analysis

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ABSTRACT

Objective: Robotic surgery is increasingly used across specialties, yet its ergonomic impact on operating room nurses remains underexplored. This multicenter study aimed to evaluate the ergonomic challenges and musculoskeletal discomfort among scrub nurses during robotic surgery and to compare these outcomes with laparoscopic procedures, with additional analysis based on years of robotic surgery experience.

Material and Methods: This cross-sectional, multicenter, questionnaire-based study was conducted between January and February 2025, among scrub nurses with experience in robotic surgery from multiple centers. Ergonomic perceptions, physical strain, musculoskeletal discomfort, and comparisons between robotic and laparoscopic surgery were assessed. Nurses were stratified into less than and more than 5 years of robotic surgery experience, and comparative statistical analyses were performed.

Results: Most nurses rated the robotic operating environment as comfortable (69.6%), and 56.4% reported reduced workload compared with laparoscopy. Physical strain was reported by 30.9%, most commonly during instrument exchange. Musculoskeletal discomfort predominantly affected the neck, back, and shoulders. Shoulder pain was significantly more common among nurses with >5 years of experience (70% vs. 33.3%, p=0.008). Although 71.4% reported ergonomic support from robotic systems, 85.7% had not received ergonomic training.

Conclusion: Robotic surgery is perceived by scrub nurses as ergonomically more favorable than laparoscopic surgery; however, substantial musculoskeletal discomfort persists, particularly among more experienced nurses and in the absence of ergonomic training. These findings suggest a potential cumulative ergonomic burden and highlight the need for structured ergonomic education and system-level interventions.

Keywords: Ergonomics, robotic surgery, scrub nurses, laparoscopy

INTRODUCTION

The rapid evolution of robotic surgery has fundamentally transformed operating room dynamics, offering ergonomic advantages primarily tailored to console surgeons. Seated posture, wrist supports, and intuitive control systems have been shown to reduce musculoskeletal strain and workload during complex procedures (1,2). Robot-assisted procedures demonstrated reduced postoperative shoulder and hand discomfort and lower physical demand when compared with conventional laparoscopy in surgical trainees and surgeons, with objectively lower muscle activity in upper limb musculature during robotic procedures (3). However, these improvements do not necessarily extend to all members of the surgical team, particularly scrub nurses, who remain physically engaged at the sterile field throughout the operation.

Unlike the console surgeon, the scrub nurse must maneuver within a constrained space, often working around bulky robotic arms with limited visual feedback or direct communication. These conditions may lead to prolonged static postures, awkward joint angles, and increased risk of musculoskeletal discomfort (4,5). In laparoscopic settings, scrub nurses have been shown to experience significant neck, back, and upper extremity discomfort, attributable to awkward positioning and extended reach for instruments outside the central surgical area (6).

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While previous research has acknowledged the ergonomic challenges faced by scrub nurses in robotic surgery, most studies have been limited to small samples, single institutions, or specific subspecialties such as urology and gynecology, and there remains a paucity of multicenter data assessing ergonomic perceptions and musculoskeletal pain among scrub nurses (7). Moreover, few have directly compared the ergonomic demands of robotic and laparoscopic surgery from the scrub nurse's perspective, even though these professionals often alternate between both modalities in routine practice.

In Türkiye, where robotic surgery is increasingly adopted across diverse clinical settings, there is a notable lack of multicenter data on scrub nurse ergonomics. Addressing this gap is critical for developing more inclusive intraoperative ergonomics protocols that account for the physical demands placed on all members of the surgical team.

In addition to describing overall ergonomic perceptions, this study specifically explores whether years of experience in robotic surgery influence ergonomic outcomes among scrub nurses. By comparing responses from nurses with more than 5 years and less than 5 years of robotic surgery experience, we aim to assess the potential cumulative ergonomic burden associated with long-term exposure to robotic procedures. This experience-based comparison provides further insight into how ergonomic challenges evolve over time within the robotic operating room environment.

MATERIAL and METHODS

Study Population

This cross-sectional, multicenter, survey-based study was conducted between January 1, 2025, and February 28, 2025. Eligible participants included nurses from multiple centers actively involved as surgical assistants in robotic procedures, with varying levels of experience and exposure to different surgical specialties, such as general surgery, urology, gynecology, and colorectal surgery. Participation was voluntary, and written informed consent was obtained from all respondents. The sample size of the study was determined based on the number of eligible scrub nurses actively involved in robotic surgery across the participating centers during the study period. A total of 12 tertiary care centers with established robotic surgery programs and high procedural volumes, where robotic surgery is routinely performed, contributed to the study, and all eligible and consenting participants were included. Due to the exploratory and descriptive nature of the study, and the limited number of specialized robotic scrub nurses in each center, a formal a priori sample size calculation was not performed. The study was approved by the Ethics Committee of Acıbadem Mehmet Ali Aydınlar University (ID: 2025-12/98, date: 10.07.2025, decision number: 2025-11/419).

Inclusion and Exclusion Criteria

Nurses were eligible for inclusion if they had participated in robotic surgical procedures as scrub nurses within the previous year and had experience with both robotic and laparoscopic surgery. Nurses without direct intraoperative involvement in robotic surgery, those exclusively working in non-robotic settings, and incomplete survey responses were excluded from the analysis.

Survey and Data Collection

The survey collected data on nurses' ergonomic perceptions, levels of physical discomfort, and their comparisons of robotic and laparoscopic surgical approaches. The responses were analyzed to identify common ergonomic issues, physical strain, and factors influencing the working environment.

The questionnaire was developed based on a review of the literature on surgical ergonomics and previously published survey-based studies evaluating ergonomic strain among surgical team members in minimally invasive and robotic surgery. Prior studies assessing first assistants and perioperative staff have commonly utilized structured questionnaires and subjective assessment tools to evaluate physical strain, musculoskeletal discomfort, and workflow-related factors (7,8). Prior to distribution, the questionnaire was reviewed by experienced surgeons and scrub nurses to ensure content validity and clinical relevance. A pilot test was conducted on a small group of nurses to assess clarity and feasibility, and minor revisions were made accordingly.

Participants completed the survey electronically. The survey required approximately 15 minutes to complete. The questionnaire consisted of 23 items organized into six main sections: demographic information, working environment and positioning, physical strain, communication and workflow, technological and ergonomic support, and overall health and well-being. Both multiple-choice and open-ended questions were included to assess physical discomfort, ergonomic challenges, perceived workload, and comparisons between robotic and laparoscopic surgery.

Participants were asked about their frequency of musculoskeletal pain, ability to reposition during surgery, physical difficulty associated with specific tasks (e.g., instrument exchange), and the impact of ergonomic conditions on job satisfaction. Perceptions of intraoperative communication, clarity of responsibilities, and adequacy of ergonomic training were also assessed.

All responses were collected anonymously and analyzed to identify common patterns and concerns related to physical strain, communication, and workflow disruptions during robotic surgery. Comparisons between robotic and laparoscopic procedures were also assessed based on perceived ergonomic advantages and workload impact.

Primary outcomes included nurses' perceived ergonomic challenges, reported musculoskeletal discomfort in various body regions, and subjective assessments of workload associated with robotic versus laparoscopic surgery. Secondary outcomes involved identifying factors influencing ergonomic strain and workplace satisfaction.

Statistical Analysis

To minimize response bias, anonymity was ensured, and no personal identifiers were collected. Categorical variables were summarized as frequencies and percentages. In addition to descriptive analyses, a comparative statistical analysis was performed between nurses with ≤5 years and >5 years of robotic surgery experience to evaluate potential differences related to cumulative exposure. Group comparisons were conducted using the chi-square test. A p-value <0.05 was considered statistically significant. Statistical analyses were performed using R statistical software (version 4.3.1).

RESULTS

A total of 56 scrub nurses participated in the survey, with a mean age of 30 years; 36 participants (64.3%) were female. Most nurses had less than 5 years of experience in robotic surgery (64.3%), while 35.7% reported more than 5 years of experience. Nearly half of the participants (47.3%) reported assisting in more than 50 robotic procedures annually. The most frequently represented surgical fields were urology (67.9%), colorectal surgery (60.7%), and gynecology (55.4%). Demographic characteristics and professional experience stratified by years of robotic surgery experience are summarized in Table 1.

Regarding the ergonomic conditions of the robotic operating environment, 39 nurses (69.6%) rated their working environment as comfortable, whereas 12.5% described it as uncomfortable. Most participants (67.9%) reported having adequate opportunities to change position during robotic surgery. No significant differences were observed between nurses with less than and more than 5 years of experience in perceived comfort or positional flexibility (Table 1).

Musculoskeletal discomfort during or following surgical procedures was commonly reported. The most frequently affected body regions were the neck (67.9%), back (58.9%), and shoulders (46.4%). Shoulder discomfort was significantly more common among nurses with more than 5 years of experience compared with those with less than 5 years (70% vs. 33.3%, p=0.008), while no statistically significant differences were observed for other body regions (Table 1). Overall, 42.9% of nurses reported frequently experiencing back, neck, or shoulder pain during surgical procedures.

Seventeen nurses (30.9%) reported experiencing physical strain during robotic instrument placement or exchange. Instrument change was identified as the most physically demanding task (35.7%), followed by surgical field organization (33.9%) and coordination with the surgical console (30.4%). These findings were consistent across experience groups, with no statistically significant differences observed (Table 1).

Most participants (71.4%) stated that the technology used during robotic surgery supported ergonomic practice. Communication and coordination within the surgical team were rated as very good by 78.6% of respondents, and 80.4% reported no factors negatively affecting workflow during robotic procedures. Clearly defined roles and responsibilities were reported by 66.1% of nurses, with no significant differences based on experience level.

A notable finding was the lack of formal ergonomic training: 48 nurses (85.7%) reported not having received any training aimed at improving ergonomics in robotic surgery. Nurses without ergonomic training reported higher levels of physical discomfort, although this did not reach statistical significance between experience groups (Table 1).

When comparing robotic and laparoscopic surgery, 79.6% of nurses perceived robotic surgery as less physically demanding, while 10.2% reported greater strain and 10.2% perceived no difference. Nearly half of the participants (49.1%) indicated that laparoscopic surgery posed greater difficulty in terms of instrument use and exchange. Robotic surgery was perceived to offer a better ergonomic working environment by 62% of nurses and to decrease workload by 56.4%, whereas 27.3% reported increased workload and 16.4% reported no change. No significant differences were observed between experience groups in comparative assessments (Table 1).

DISCUSSION

This multicenter survey provides a comprehensive perspective on the ergonomic challenges experienced by scrub nurses during robotic surgery, a population that has been relatively underrepresented in ergonomic research, which has traditionally focused on console surgeons. In minimally invasive and robotic surgery, scrub nurses have evolved from passive assistants to active members of the surgical team, requiring a detailed understanding of surgical steps and instrument management, which may contribute to increased physical and cognitive demands (9). Although most nurses perceived robotic surgery as ergonomically more favorable than laparoscopy, a considerable proportion reported persistent musculoskeletal discomfort, particularly in the neck, back, and shoulders. These findings are consistent with previous reports indicating that the ergonomic advantages of robotic platforms may not extend uniformly to all members of the surgical team (4).

Robotic systems are well known to reduce physical fatigue for surgeons by enabling seated operation, wrist support,

Table 1. Demographic characteristics, ergonomic perceptions, musculoskeletal discomfort, and comparison of robotic versus laparoscopic surgery among scrub nurses, stratified by years of robotic surgery experience				
	Total	**≤5 years**	**>5 years**	**p-value**
Gender				
Male	20 (35.7)	7 (35)	13 (36.1)	0.934
Female	36 (64.3)	13 (65)	23 (63.9)	
Years of experience working as a bedside nurse in robotic surgery				
0-1	14 (25)			
2nd May	22 (39.3)			
10+	8 (14.3)			
6th Oct	12 (21.4)			
Experience (years)				
>5	20 (35.7)			
≤5	36 (64.3)			
Field of working in robotic surgery				
Bariatric	14 (25)	8 (22.2)	6 (30)	0.52
Colorectal	34 (60.7)	19 (52.8)	15 (75)	0.103
Urology	38 (67.9)	22 (61.1)	16 (80)	0.147
Upper GI	21 (37.5)	13 (36.1)	8 (40)	0.773
Gynecology	31 (55.4)	18 (50)	13 (65)	0.279
The ergonomics of your current working environment during robotic surgery				
Comfortable	39 (69.6)	23 (63.9)	16 (80)	0.191
Neither comfortable nor uncomfortable	10 (17.9)	9 (25)	1 (5)	
Uncomfortable	7 (12.5)	4 (11.1)	3 (15)	
Musculoskeletal pain in the back, neck, or shoulder regions while working during surgical procedures				
Frequently	24	0.429		
Sometimes	17	0.304		
Rarely	10	0.179		
No	5	0.089		
The body regions you experience discomfort during or following surgical procedures				
Neck	38 (67.9)	25 (69.4)	13 (65)	0.733
Shoulder	26 (46.4)	12 (33.3)	14 (70)	0.008
Back	33 (58.9)	22 (61.1)	11 (55)	0.656
Arm	6 (10.7)	4 (11.1)	2 (10)	>0.999
Leg	20 (35.7)	16 (44.4)	4 (20)	0.086
Foot	12 (21.4)	9 (25)	3 (15)	0.506
Adequate opportunity to change position during robotic surgery				
Yes	38 (67.9)	22 (61.1)	16 (80)	0.233
No	18 (32.1)	14 (38.9)	4 (20)	
Pysical strain when placing or exchanging surgical instruments during robotic surgery				
Yes	17 (30.9)	13 (36.1)	4 (21.1)	0.36
No	38 (69.1)	23 (63.9)	15 (78.9)	

Table 1. Continued				
	Total	**≤5 years**	**>5 years**	**p-value**
Activities physically most demanding during robotic surgery				
Instrument change	20 (35.7)	15 (41.7)	5 (25)	0.256
Positioning of the camera	12 (21.4)	7 (19.4)	5 (25)	0.737
Organisation of surgical field	19 (33.9)	13 (36.1)	6 (30)	0.772
Coordination with the surgeon at the console	17 (30.4)	10 (27.8)	7 (35)	0.762
Level of communication and coordination within the surgical team				
Very poor	2 (3.6)	2 (5.6)	0 (0)	0.638
Neutral	10 (17.9)	7 (19.4)	3 (15)	
Very good	44 (78.6)	27 (75)	17 (85)	
Any factors that negatively affect workflow during robotic surgery				
Yes	11 (19.6)	7 (19.4)	4 (20)	>0.999
No	45 (80.4)	29 (80.6)	16 (80)	
Clearly defined roles and responsibilities during robotic surgery				
Yes	37 (66.1)	23 (63.9)	14 (70)	0.644
No	19 (33.9)	13 (36.1)	6 (30)	
The technology used during robotic surgical procedures supports ergonomic practice				
Yes	40 (71.4)	25 (69.4)	15 (75)	0.659
No	16 (28.6)	11 (30.6)	5 (25)	
Physical strain experienced during robotic surgical procedures affects overall health				
Yes	25 (44.6)	15 (41.7)	10 (50)	0.548
No	31 (55.4)	21 (58.3)	10 (50)	
Any received formal training aimed at enhancing ergonomics in robotic surgery				
Yes	8 (14.3)	4 (11.1)	4 (20)	0.437
No	48 (85.7)	32 (88.9)	16 (80)	
Ergonomics of robotic surgery affecting overall job satisfaction				
Yes, positively affects	23 (41.1)	15 (41.7)	8 (40)	>0.999
Neutral	27 (48.2)	17 (47.2)	10 (50)	
No, negatively affects	6 (10.7)	4 (11.1)	2 (10)	
Comparison of laparoscopic and robotic surgical procedures in terms of physical strain				
Robotic surgery is associated with less physical strain	39 (79.6)	24 (77.4)	15 (83.3)	0.869
Robotic surgery is associated with more physical strain	5 (10.2)	4 (12.9)	1 (5.6)	
Robotic surgery is equally physically demanding as laparoscopic surgery	5 (10.2)	3 (9.7)	2 (11.1)	
Which surgical approach poses greater difficulty in terms of instrument use and exchange				
Both are similar	9 (17)	7 (20.6)	2 (10.5)	0.509
Laparoscopic surgery	26 (49.1)	17 (50)	9 (47.4)	
Robotic surgery	18 (34)	10 (29.4)	8 (42.1)	
Which surgical approach offers a better ergonomic working environment for bedside nurses				
Both are similar	12 (24)	10 (33.3)	2 (10)	0.167
Laparoscopic surgery	7 (14)	4 (13.3)	3 (15)	
Robotic surgery	31 (62)	16 (53.3)	15 (75)	

Table 1. Continued				
	Total	**≤5 years**	**>5 years**	**p-value**
Robotic surgical systems reduce or increase workload when compared with laparoscopic procedures				
No change	9 (16.4)	8 (22.9)	1 (5)	0.234
Increases workload	15 (27.3)	9 (25.7)	6 (30)	
Decreases workload	31 (56.4)	18 (51.4)	13 (65)	
GI: Gastrointestinal.				

improved visualization, and enhanced dexterity (1,2). However, scrub nurses remain physically active at the bedside, frequently working in spatially constrained environments around rigid robotic arms. Prior studies have shown that assistants are exposed to prolonged static postures and awkward joint positions during minimally invasive surgery (6). van't Hullenaar et al. (7) demonstrated that first assistants, who perform tasks comparable to those of scrub nurses, frequently assume high-risk ergonomic postures during robot-assisted surgery, particularly during instrument exchange and intraoperative coordination. In accordance with these findings, more than one-third of nurses in our study identified instrument exchange as the most physically demanding task, followed by surgical field organization and coordination with the surgical console.

A key strength of the present study is the experience-based subgroup analysis. Shoulder discomfort was significantly more common among nurses with more than five years of robotic surgery experience compared with those with less experience, suggesting a potential ergonomic burden associated with long-term exposure. This observation adds a novel dimension to the existing literature, which has largely relied on descriptive survey data without examining the impact of cumulative experience on ergonomic outcomes among scrub nurses.

Task-specific strain emerged as an important contributor to musculoskeletal discomfort. Activities such as instrument exchange, organization of the surgical field, and coordination with the console require sustained upper-body engagement, repetitive reaching, and continuous attention, all of which are recognized risk factors for work-related musculoskeletal disorders in perioperative personnel (3,5). These findings highlight that ergonomic risk in robotic surgery is not solely technology-related but also task-driven, emphasizing the need for workflow-oriented ergonomic interventions.

Another striking finding was the lack of formal ergonomic training, with 85.7% of participants reporting no education aimed at improving ergonomic practice in robotic surgery. Previous studies have demonstrated that structured ergonomic education can reduce musculoskeletal symptoms by improving posture awareness, task modification, and early recognition of strain-related risks (10,11). A recent systematic review by Møller et al. (12) further emphasized that ergonomic training programs tailored to nurses involved in robotic surgery can significantly mitigate physical discomfort and improve occupational well-being. The absence of such training in our cohort may partly explain the persistence of musculoskeletal complaints despite favorable perceptions of robotic systems.

Beyond individual-level interventions, organizational and system-level strategies play a crucial role in mitigating ergonomic strain. Adjustable-height operating tables, optimized monitor placement, anti-fatigue mats, and scheduled intraoperative microbreaks have all been associated with reductions in physical strain and improved team performance (13,14). Although more than 70% of nurses in our study acknowledged that robotic systems supported ergonomic practice, the persistence of discomfort suggests that environmental design alone is insufficient without structured ergonomic implementation. The establishment of dedicated roles, such as the perioperative robotics nurse specialist, has been proposed as a means of institutionalizing ergonomic standards and ensuring consistency in education and practice (15).

At a broader level, these findings underscore the importance of integrating ergonomic considerations into institutional policies and surgical quality frameworks. Incorporating ergonomic risk assessments into robotic surgery programs and accreditation processes may help recognize musculoskeletal strain as an occupational hazard and promote nurse well-being (16). Furthermore, interdisciplinary collaboration between surgeons, nurses, biomedical engineers, and ergonomists is essential to guide the development of more user-centered robotic systems. Emerging innovations, including modular robotic arms, real-time posture monitoring, and ergonomically adaptive system design, hold promise for reducing physical workload across the surgical team (17).

Study Limitations

This study has several limitations. First, ergonomic strain and musculoskeletal discomfort were assessed exclusively using self-reported measures, without the use of objective ergonomic assessment tools such as RULA, REBA, or electromyography. This may limit the objectivity and precision of the findings. The sample size was modest (n=56), reflecting the limited number of scrub nurses actively involved in robotic surgery across

participating centers, which may restrict the generalizability of the findings.

In addition, direct statistical comparison between robotic and laparoscopic surgery groups was not feasible due to the study design. However, we performed a comparative statistical analysis between nurses with less than 5 years and more than 5 years of robotic surgery experience, which adds analytical depth and addresses cumulative exposure effects. Potential confounders such as procedure duration, case complexity, and operating room layout could not be controlled. Despite these limitations, the experience-based subgroup analysis provides novel insight into ergonomic strain among scrub nurses and strengthens the contribution of this study to existing literature.

CONCLUSION

In summary, while robotic surgery is generally perceived by scrub nurses to offer ergonomic advantages over laparoscopy, persistent musculoskeletal challenges remain, particularly among more experienced nurses and in the absence of ergonomic training. Addressing these issues through structured education, workflow optimization, and system-level ergonomic interventions is essential to ensure that the benefits of robotic surgery extend to all members of the surgical team and support sustainable surgical practice.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of Acıbadem Mehmet Ali Aydınlar University (ID: 2025-12/98, date: 10.07.2025, decision number: 2025-11/419).

Informed Consent: Written informed consent was obtained from all participants prior to their inclusion in the study.

Footnotes

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Author Contributions

Concept - Ö.B., İ.A.B., İ.V., S.G., B.B.; Design - Ö.B., İ.A.B., İ.V., S.G., B.B.; Data Collection or Processing - N.R., İ.A.B., D.A., A.U.M., İ.V., S.G., M.A.B.; Analysis or Interpretation - Ç.B., D.A., B.B.; Literature Search - Ç.B., N.R., İ.V., S.G.; Writing - Ç.B., N.R., İ.A.B., M.A.B., B.B.

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