Surgery 195 (2026) 110049

Contents lists available at ScienceDirect

Surgery

journal homepage: www.elsevier.com/locate/surg

ERGO (ERGonomics in the Operating room) study: A cross-sectional international online survey

Stefano Restaino, MD[a,b,*], Nicoletta Crivellaro, MD[a,c], Federico Paparcura, MD[a,c], Gianluca Pellino, MD, PhD[d,e], Mauro Podda, MD[f], Alice Poli, MD[a,c], Giulia Pellecchia, MD[a,c], Martina Arcieri, MD, PhD[a], Federica Perelli, MD[g], Marco D'Indinosante, MD[h], Benedetto Ielpo, MD, PhD[i], Marcello Di Martino, MD, PhD[j], Giovanni Scambia, MD[h], Lorenza Driul, MD[a,c], Giuseppe Vizzielli, PhD, MD[a,c], Francesco Pata, MD, PhD[k,l], ERGO Collaborative Group

[a] Department of Maternal and Child Health, Obstetrics and Gynecology Clinic, University Hospital of Udine, Udine, Italy
[b] PhD School in Biomedical Sciences, Gender Medicine, Child and Women Health. University of Sassari, Sassari, Italy
[c] Department of Medicine (DMED), University of Udine, Udine, Italy
[d] Colorectal Surgery Department of General Surgery, Vall d'Hebron University Hospital, Universitat Autonoma de Barcelona UAB, Barcelona, Spain
[e] Department of Advanced Medical and Surgical Sciences, Universitá degli Studi della Campania "Luigi Vanvitelli," Naples, Italy
[f] Department of Surgical Science, University of Cagliari, Cagliari, Italy
[g] Department of Gynecology and Pediatrics, Azienda USL Toscana Centro, Florence, Italy
[h] Department of Woman, Child Health and Public Health, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy
[i] Hepato-Biliary and Pancreatic Surgery Unit, Department of Surgery, Hospital del Mar, Pompeu Fabra University, Barcelona, Spain
[j] Colorectal Surgery, Department of General and Digestive Surgery, Vall d'Hebrón University Hospital, Universitat Autonoma de Barcelona UAB, Barcelona, Spain
[k] Department of Pharmacy, Health and Nutritional Sciences, University of Calabria, Rende, Italy
[l] Department of Surgery, General Surgery Unit, A.O. Annunziata, Cosenza, Italy

ARTICLE INFO

Article history:
Accepted 30 November 2025
Available online 16 February 2026

ABSTRACT

Introduction: Although work-related physical disorders among surgeons are increasing globally, with potential detrimental effects on surgical performance and patient care, ergonomics is still overlooked in clinical practice. The aim of this study is to investigate ergonomics problems and perceptions in the operating room in an international cohort of surgeons to obtain baseline data necessary to plan implementation initiatives.

Methods: A Checklist for Reporting Results of Internet E-Surveys (CHERRIES)—compliant internet-based survey was developed using Google Forms and distributed via surgical societies, professional associations, and collaborative networks between September 2023 and February 2024 to surgeons from different specialties worldwide. The survey consisted of 6 sections, exploring various aspects such as job history, surgical specialty, practice location and role, surgical training, and injuries related to surgical practice. A total of 1,093 responses were received from surgeons in 42 countries. Because of the open distribution model, a precise response rate could not be calculated. The decision to use an online survey as the primary data collection method was driven by several distinct advantages. Primarily, this approach facilitated access to a broad and heterogeneous sample of surgeons encompassing various specialties and geographic locations—an achievement challenging to replicate with conventional survey techniques. The digital format enabled efficient dissemination through established channels, including surgical societies, professional organizations, and collaborative networks, thereby ensuring extensive reach in a cost-effective and timely fashion. Moreover, the anonymity afforded by the online platform encouraged participants to provide honest and uninhibited responses concerning sensitive topics such as musculoskeletal discomfort and ergonomic behaviors, mitigating potential biases linked to social desirability or fear of professional consequences. The flexibility inherent to an internet-based survey

Giuseppe Vizzielli and Francesco Pata shared senior authorship.

* Corresponding author: Stefano Restaino, MD, PhD School in Biomedical Sciences, Gender Medicine, Child and Women Health, University of Sassari, Sassari, Italy; Department of Maternal and Child Health, Obstetrics and Gynecology Clinic, University Hospital of Udine, P.le Santa Maria della Misericordia, 1, Udine 33100, Italy.
E-mail address: stefano.restaino@asufc.sanita.fvg.it (S. Restaino).

https://doi.org/10.1016/j.surg.2025.110049
0039-6060/© 2025 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

also allowed respondents to participate at their convenience, which likely enhanced overall response rates and engagement among busy health care professionals worldwide. Collectively, these attributes positioned the online survey as an optimal and practical tool for capturing comprehensive baseline data on ergonomic issues within the international surgical community.

Results: The survey received a total of 1,093 responses. Up to 96.9% of surgeons reported experiencing some musculoskeletal discomfort, which were more commonly associated with laparoscopy (55.4%), followed by open surgery (32.9%). Robotic surgery had the lowest rate of pain (1.1%, $P < .001$). Surgery-related injuries in 9.7% of cases prevented the surgeon from performing clinical or surgical duties, and in 13.4% of cases musculoskeletal pain necessitated absence from work or job leave. Overall, 31.4% of the respondents implemented risk mitigation strategies in the operating room with microbreaks and intraoperative stretching. Seventy-three percent of the responders have never followed formal training, lectures, or discussions about ergonomics.

Conclusion: Laparoscopic surgery significantly impacts surgeons; to mitigate the effects of musculoskeletal disorders on individual surgeons and the broader surgical workforce, innovations such as robotic surgery and ergonomic education may offer potential benefits; these descriptive findings highlight the need for further research to evaluate their role in reducing the burden of work-related musculoskeletal issues.

© 2025 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Introduction

There is an increased body of evidence that ergonomics and work-related disorders play a pivotal role in surgeon's health with impact on productivity, carrier longevity, and patient care.[1]

Twelve percent of physicians face practice restrictions, sick leave, or early retirement due to work-related factors with a documented increase by 18.3% and 27% in degenerative disorders of the cervical and lumbar spine among surgeons observed between 1997 and 2015.[2] Surgical practice is physically demanding, and although the introduction of laparoscopic surgery has improved patient outcomes and postoperative recovery, it has also exacerbated ergonomic issues for surgeons.[3] Prolonged static posture during laparoscopic procedures, 2-dimensional vision, nonarticulated instruments with limited degrees of freedom, and long-lasting complex procedures induce stress that may have a great impact on surgeon performance and on career longevity in the long term.[4]

Robot-assisted surgery appears to exhibit a better ergonomic profile thanks to sitting position, 3-dimensional visualization, and less demanding suturing technique.[5] Different activation patterns have been also observed, with less activity especially in neck and shoulder muscles.[6,7] However, despite these advancements, robotic surgeons still report operating room–related symptoms such as neck stiffness and forearm, finger, and eye fatigue.[6,8]

To address these issues, the American College of Surgeons (ACS) and the US Occupational Safety and Health Administration (OSHA) issued a set of guidelines.[9,10]

Understanding ergonomics can improve surgeons' comfort in the operating room and reduce their physical strain. Addressing these issues by enhancing techniques to minimize work-related injuries among surgeons is becoming increasingly important. These methods include incorporating stretching, taking mini-breaks during operations, adopting more ergonomic postures, and using ergonomic instruments.[11–13] However, international data on the topics are still lacking. This study aims to fill a crucial gap in knowledge regarding the insufficient global insight into how prevalent ergonomic problems are among surgeons, especially considering the growing use of robotic surgery and the various approaches implemented to address these concerns. An online survey was chosen as the most effective method for this research because it allows access to a wide and diverse international group of surgeons and trainees from different specialties and work environments, facilitating the gathering of detailed and practical information about their ergonomic experiences and habits.

The aim of this study was to investigate ergonomics issues on a worldwide cohort of surgeons and surgical trainees to have an updated overview of the topic, considering the widespread adoption of robotics, and about the mitigation strategies adopted to overcome these.

Material and methods

The Unit of Gynecology of the University of Udine (Italy) in collaboration with the Italian Society of Surgical trainees (SPIGC), the Association of Italian Surgeons in Europe (ACIE), and the Italian Surgical Research Group (ItSURG) has developed a web-based cross-sectional survey to detect ergonomics issues in the operating activities of surgeons and trainees.

The ERGO (ERGonomics in the Operating room) questionnaire (https://docs.google.com/forms/d/e/1FAIpQLSdP2BwEIHBayNw1iH92vRAmh2bVWo0aLU2z0DfSt0tgNcPEHA/viewform?usp=pp_url) was a confidential (identified) web-based survey disseminated from September 2023 to February 2024 to surgeons and surgical residents of different surgical specialties (General Surgery, Gynecology and Urology) worldwide. Participation in the survey was open to all eligible surgeons and trainees via targeted email invitations (~1,350 distributed) and posts shared through the SPIGC, ItSURG, and ACIE networks, ensuring broad international reach. No incentives were provided. Among respondents who started the survey, completion—defined as submission of all 5 sections—was achieved by 1,093 participants, corresponding to a completion rate of approximately 80%. Because of the open-access nature of social media and newsletters, unique site visitors and participation/view rates could not be precisely determined; therefore, no overall response rate was calculated, in accordance with the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) recommendations.

This survey was developed and reported following CHERRIES.[14] Formal ethical approval was not required, as participation was voluntary, confidential, and did not involve patient data. Digital informed consent was obtained on the first page of the survey, prior to accessing any study questions. Participants who did not provide consent were automatically redirected out of the form, and no data were stored. Although respondents could optionally provide their name, surname, and ORCID for authorship indexing and deduplication, 1,080 of 1,095 respondents ($\approx$98.6%) provided ORCID identifiers. For the 15 participants without ORCID, potential duplicates were assessed using demographic data and response patterns. All identifiers were stored in separate, password-

protected data set, accessible only to the Steering Committee, and were used exclusively to ensure unique participation and to credit contributors appropriately. After data cleaning and deduplication, the analytic data set was fully deidentified prior to statistical analysis, with all identifiers permanently removed. To prevent duplicate submissions, the Google Forms platform restricted responses to 1 per account and used IP throttling to limit repeated access from the same device. Additionally, post hoc screening was performed to identify potential duplicates based on identical ORCID, demographic data, and response patterns; in such cases, only the most complete entry was retained. Incomplete questionnaires were included in the analysis if at least 80% of items were completed. For item nonresponse, a pairwise deletion approach was applied. Each table and figure reports the analytic sample size (N) used in that specific analysis. A sensitivity analysis comparing complete and partial respondents revealed no significant demographic or outcome differences.

The Steering Committee designed the questionnaire through web-based and remote discussions following the identification of key components and topics to be included. Prior to its official implementation, the questionnaire underwent an initial beta-testing phase to assess its clarity, relevance, and ease of use. The average completion time was approximately 15 minutes. Branching logic was employed to tailor the survey path based on respondents' previous answers, enhancing relevance and reducing completion time. On reaching a consensus, the final version of the questionnaire, titled The ERGO (ERGonomics in the Operating room) Study Form was developed using Google Forms survey software (Google, Mountain View, CA).

The questionnaire comprised 5 sections (personal details, hospital organization, laparoscopic experience and training, robotic experience and training, ergonomics) with a total of 56 questions (Supplementary Table S1), incorporating both closed-ended (44 of 56) and open-ended (12 of 56) formats. The first 2 sections gathered general information regarding respondents' baseline characteristics, including their country and continent of practice, specialty, years of professional experience, level of practice, and hospital organization. The remaining sections focused on aspects of clinical practice, training and operating room ergonomics, such as the incidence and frequency of work-related injuries, the relationship between these and the operating room's setting, and whether these injuries impacted personal life or required mitigation strategies to prevent them.

We evaluated the relationship between surgical modality (laparoscopic, open, or robotic) and the incidence of musculoskeletal pain using the χ^2 test of independence.

Each respondent obtained an overview of the study at the start of the survey with a guarantee of confidentiality and consented or refused to be included in the collaborative group in the resulting publications.

After the study deadline, the results were downloaded and analyzed using SPSS version 19.0 (IBM, Armonk, NY). Quantitative variables were described using means and SDs or medians and interquartile ranges, depending on the type of distribution. Qualitative variables were summarized using absolute and percentage frequency tables. Groups were compared using the *t* test or Kruskal-Wallis test for continuous variables and the χ^2 test or Mann-Whitney test for categorical variables as appropriate. For all comparisons, absolute differences with 95% confidence intervals (CIs) were calculated. Where clinically meaningful, absolute risk reduction, absolute risk increase, and number needed to treat/harm proxies were computed to complement *P* values.

Results

The survey was completed by 1,093 surgeons. General surgery was the most represented specialty, with 915 participants (83.7%), followed by gynecology with 158 participants (14.5%). Regarding the countries represented, 923 (84.4%) of the participants were from Europe, 60 (5.5%) from Asia, 55 (5.0%) from America, and 53 (4.8%) from Africa (Figure 1). Men made up 73.1% of the population, and women 26.9%. The age group between 31 and 40 years was the most represented (47.7%). Regarding the roles of the participants, 564 (51.6%) were consultant/attending surgeons, 266 (24.3%) were trainees/fellows, and 216 (19.8%) were university professors or researchers. Table I provides a summary of the participants' characteristics.

Of the total respondents, 1,049 (96.9%) reported experiencing musculoskeletal discomfort due to inadequate ergonomics at work. Figure 2 summarizes the most affected areas. Analyzing the frequency of pain occurrence, 79 (7.2%) experienced daily pain after surgery, 306 (28.0%) reported pain occurring once a week, and 531 (48.6%) experienced pain monthly. Laparoscopy had the highest correlation with these disorders (55.4%), followed by open surgery (32.9%), whereas robotic surgery had the lowest rate of

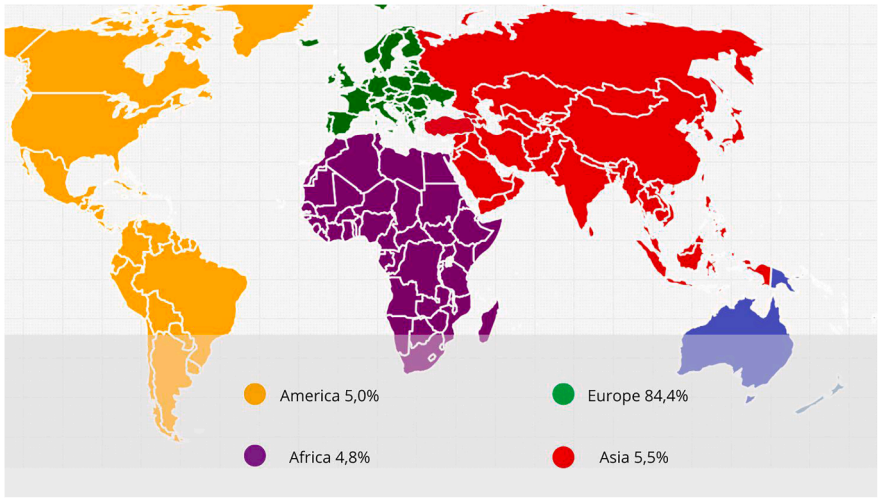

Figure 1. Percentage of participants divided by continents.

Table I
Participants' features

	Percentage	No. of participants (total N = 1,093)
Gender		
Female	26.9	294
Male	73.1	799
Age group		
<30 y	10.0	109
31–40 y	47.7	521
41–50 y	24.9	272
>50 y	17.5	191
Years in practice		
1–5	37.5	410
6–10	20.1	220
11–20	20.1	220
21–30	10.5	115
>30	8.2	90
Role of surgeons		
Consultant/attending	51.6	564
University professor researcher	19.8	216
Trainee/fellow	24.3	266
Resident	1.6	47
Practice setting		
University public hospital	78.1	854
Public hospital	8.9	97
Private hospital	10.7	117
Private university hospital	2.3	25
Continent of origin of the participants		
Europe	84.4	923
Asia	5.5	60
Africa	4.8	55
America	5.0	53
Type of speciality		
General surgery	83.7	915
Subspecialty	Percentage (of 915)	n
Upper GI	6.3	58
Colorectal	28.8	263
Hepato-pancreato-biliary	13.8	126
Emergency surgery	8.4	77
Breast surgery	3.0	27
Abdominal wall	2.5	23
Endocrine	1.9	17
Transplantation surgery	1.6	15
Pediatric surgery	3.8	35
General surgery	29.9	274
Gynecology	14.5	158
Urology	1.8	20

pain (1.1%, $P < .001$). A total of 855 respondents (78.2%) sustained a musculoskeletal injury in the operating room.

Regarding the issues, 30.3% (331 participants) occurred during surgery, 19.8% (216 participants) were observed 3 hours after, 14.4% (159 participants) experienced issues between 3 and 12 hours postsurgery, 13.3% (145 participants) reported problems the day after the operation, 13.2% (144 participants) experienced symptom onset between 30 minutes and 1 hour after surgery, whereas 9% (98 participants) reported issues within 30 minutes. Because of these discomforts, 481 (44.0%) practitioners needed to stop for a short rest or perform some exercise to reduce pain. The back (60.5%), neck (56.4%), and shoulders (52.2%) were the body parts most afflicted. Additionally, 743 respondents (68.0%) reported that the position of the monitors in the operating room contributed to their pain. Specifically, 550 participants (50.3%) had 2 monitors, 322 (29.5%) had only 1, 162 (14.8%) had 3, and 59 (5.4%) had 4 available.

A total of 715 respondents (65.4%) said they did not use any methods to relieve discomforts, whereas 209 (19.1%) used elastic compression stockings and 116 (10.6%) performed surgeries in a sitting position (using a chair) during laparoscopy. Furthermore, it was reported that surgery-related injuries prevented the surgeon from performing clinical or surgical duties in 9.7% of cases. In 146 participants (13.4%), musculoskeletal pain necessitated absence from work or job leave. Moreover, in 241 respondents (22.1%), these injuries prevented the surgeon from performing activities outside the hospital or clinic.

A total of 608 respondents (55.6%) had never consulted physicians for treatments or consultations after experiencing pain or muscle strain; 249 (22.8%) went to physiotherapists, and 236 (21.6%) to a massage therapist.

Overall, 31.4% of responders implemented risk-mitigation strategies in the operating room with microbreaks and intraoperative stretching, 45.2% of them routinely perform stretching or exercises for specific muscle groups outside the surgery room to relieve musculoskeletal pain and aches. A total of 798 respondents (73%) had never received formal training, lectures, or discussions about ergonomics. More than three-fourths (77.7%) of the responders believed that greater emphasis on ergonomics education for medical students and surgical residents in these areas is required. Surgery-related pain characteristics are summarized in Table II.

Analysis of the subgroups revealed a statistically significant difference in the types of surgery that cause greater discomfort across the various specialties. Urologists experience more discomfort from laparoscopy compared with general surgeons and gynecologists. Conversely, gynecologists reported higher discomfort with transvaginal surgery (P value <.001). When comparing surgeons and residents, the former report greater discomfort with laparoscopy, whereas the latter reported greater discomfort with laparotomy (P value = .003). The results are summarized in Table III.

Regarding the most affected body areas, no statistically significant differences emerged among the different specialties (Table IV).

Discussion

This is the first large-scale, international survey focused specifically on ergonomics and musculoskeletal disorders in the operating room across a diverse range of surgical specialties and geographic regions. The robust sample size (n = 1,093) collected from surgeons and trainees across 4 continents provides a comprehensive snapshot of current ergonomic practices and occupational health burdens. It is important to note that most responses were from male surgeons, highlighting the existing gender disparities in the surgical field. Although the number of female surgeons is gradually increasing, they remain a minority worldwide, as confirmed by recent studies.[15] Although there is hope for improvement and progress is being made, further efforts are needed to address this imbalance.

According to our survey, laparoscopy is the surgical approach most associated with discomfort, as 55.4% of participants reported. This finding aligns with the data available in the literature. During surgery, the surgeon can easily adopt nonergonomic positions because of the surgical technique, as well as patient characteristics and the anatomic site of the procedure. This occurs more frequently in laparoscopy, where prolonged static postures and repetitive movements are more common. As emerges from the study by Pérez-Salazar et al,[3] when comparing laparoscopic surgery with robotic surgery, the latter offers several advantages, including enhanced wrist and articulated movements, high-definition 3-dimensional imaging, and the ability for the surgeon

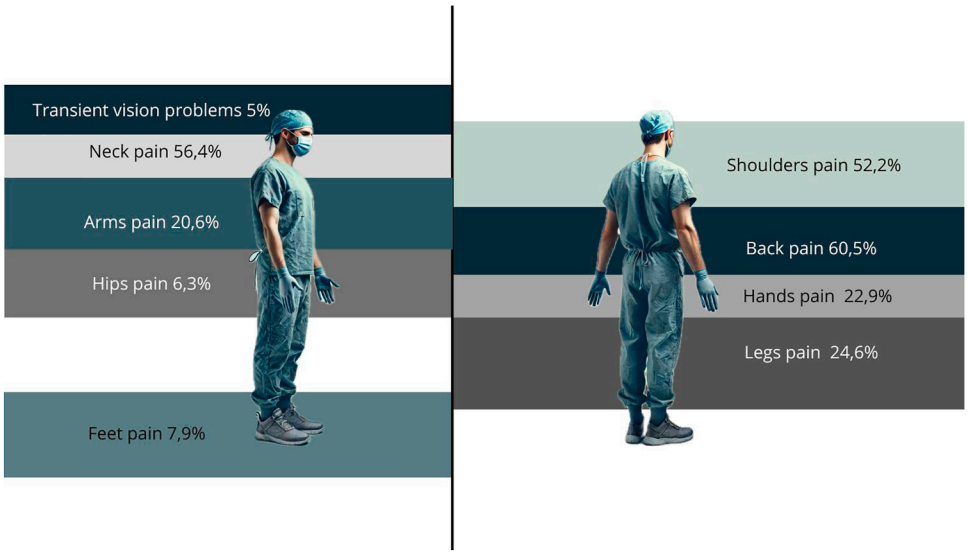

Figure 2. Areas of the body perceived as more uncomfortable.

to perform the procedure while seated. All these factors contribute to improved ergonomics. Although it appears to be less impactful, as highlighted in our study, robotic surgery can still lead surgeons to maintain nonergonomic positions that may cause musculoskeletal discomfort. Figure 3 illustrates the main postural errors associated with this type of surgery.

Our findings indicate that the neck, shoulders, and lower back are the most affected areas, with rates of musculoskeletal issues comparable to those reported in the existing scientific literature.[16–18] A systematic review by Jacquier-Bret et al,[19] published in 2023, analyzed 36 studies and found that surgeons had the highest prevalence of lower back musculoskeletal disorders (>60%); the primary causes were linked to maintaining and repeating awkward postures.

Table II
Surgical-related pain

	Percentage
Feeling that body in an uncomfortable position in the operating room. muscle aches or pain during retraction, assistance, or surgery	
Yes	96.9
No	3.1
How often do pains occurs	
Annually	16.2
Monthly	48.6
Weekly	28
Daily	7.2
Areas of the body that are most uncomfortable	
Neck	56.4
Shoulders	52.2
Back	60.5
Hips	6.3
Legs	24.6
Feet	7.9
Arms	20.6
Hands	22.9
Eyes (transient vision problems)	5
Reported correlation between arrangements of monitors layout and neck pain	
Yes	68
No	32
Devices to prevent the onset of these complains	
Elastic compression stockings	19.1
Sitting position (on a chair) during laparoscopy	10.6
None	65.4
Perform reduction strategies in the operating room to alleviate musculoskeletal problems	
Yes	31.4
No	68.6

A 2022 study by Michael et al,[20] which focused on minimally invasive surgery, revealed that injury sites included back pain, neck pain, and upper extremity issues such as shoulder pain, tennis elbow, and carpal tunnel syndrome. Furthermore, over two-thirds of respondents were unaware of potential ergonomic solutions and had yet to consider adopting preventive measures.

A study by Franasaik et al[21] developed an ergonomics design framework for robotic surgery to demonstrate correct body positioning and strategies to avoid incorrect postures. The results showed that 88% of participants improved their habits in the operating room, and 74% reduced physical stress during robotic surgery after completing the training course. This article shows how correct information and preparation on ergonomics in the operating room can be the key to reducing these problems. Ergonomic training is needed during surgical residency to help surgeons develop proper posture and incorporate stretching exercises, which may help prevent long-term physical problems later in their careers. It is now imperative that resident programs include ergonomics in the operating room to better prepare surgeons for operative procedures and extend their careers. Additionally, surgical time-outs should include reminders on proper posture to ensure correct operating room setup and enhance surgical team members' adherence to ergonomic principles.

Although patient care is crucial, providing the best treatment also requires prioritizing the physical and mental well-being of surgeons. Without this, surgeons may face physical problems and increased work absences due to preventable illnesses. Incorporating ergonomics into surgical practice can significantly contribute to this goal by enhancing surgeon comfort and reducing the risk of work-related issues.

A notable strength of this study is its global overview of illnesses related to the surgical profession, a topic that is often underexplored. Additionally, the study provides valuable insights into the prevalence of musculoskeletal disorders among surgeons and emphasizes the importance of ergonomic training, which can lead to improved surgical outcomes and increased career

Table III
Highest reported discomfort by surgical approach

Types of Surgeon	Laparoscopic	Open	Robotic	Transvaginal/ Transanal	*P* value
General surgery	509 (56)	322 (35)	11	73 (8)	<.001
Gynecology	81 (51)	34 (21)	1	42 (27)	
Urology	15 (75)	4 (20)	0	1 (5)	
Resident	136 (47)	119 (41)	5	32 (10)	.003
Surgeon	469 (59)	241 (30)	7	84 (10)	

Table IV
Prevalence of physical discomfort by anatomic region across specialties and roles

Specialities	Neck	Shoulders	Back	Hips	Legs	Feet	Arms	Hands	Eyes	*P* value
General surgery	527 (22)	471 (20)	566 (24)	61 (3)	230 (9)	72 (3)	185 (7)	222 (9)	50	.318
Gynecology	77 (21)	87 (24)	82 (23)	4	32 (9)	13 (4)	35 (10)	23 (6)	5	
Urology	12 (20)	13 (22)	13 (22)	4 (7)	6 (10)	1	5 (8)	5 (8)	0	
Resident	164 (20)	144 (18)	197 (24)	21 (3)	90 (11)	37 (5)	69 (9)	62 (8)	15	.013
Surgeon	452 (23)	427 (22)	464 (23)	48	178 (9)	49	156 (8)	188 (9)	40	

longevity. However, this study has several limitations. First, although the survey included surgeons from across 4 continents, the sample was heavily weighted toward Europe (84.4%), which may limit the generalizability of findings. Second, the reliance on self-reported data introduces the potential for recall bias and subjective underreporting of symptoms. Third, although we compared discomfort prevalence across surgical techniques, we did not assess the anatomic distribution of musculoskeletal pain within each surgical modality (eg, whether neck pain was more prevalent in laparoscopy versus robotic surgery). This limits our ability to associate specific ergonomic burdens with particular body regions. Further, the survey did *not* include questions on respondents' baseline level of physical activity or exercise. Although such data would have been self-reported and subject to bias, they could have provided valuable context for interpreting the prevalence of musculoskeletal discomfort and might have helped clarify whether baseline activity confounds or moderates the association between surgical practice and reported ergonomic symptoms. Last, the survey did not include objective ergonomic assessments or longitudinal tracking of injury development, which should be considered in future studies aiming to evaluate cause-effect relationships and preventive strategies.

Future research should prioritize objective ergonomic assessments and longitudinal studies to gain a deeper understanding of the long-term effects of poor posture and to identify effective preventive strategies. Efforts should also be directed toward developing comprehensive ergonomics training programs, optimizing equipment positioning and adjustments in the operating room, and conducting detailed postural analyses to reduce the risk of surgery-related health issues. Additionally, visual fatigue is an important area that warrants further investigation, particularly in relation to the impact of prolonged monitor use on the visual field. Ultimately, improved ergonomic practices in surgery can lead to more precise and effective patient care.

Conclusion

Laparoscopic surgery significantly impacts surgeons' health; to mitigate the effects of musculoskeletal disorders on individual surgeons and the broader surgical workforce, innovations such as robotic surgery and improved ergonomic education may offer potential benefits in reducing the prevalence of work-related musculoskeletal issues. These findings suggest that strategies such as fatigue management programs, preoperative stretching exercises, physical fitness initiatives, and formal ergonomics training could represent valuable areas for future quality-improvement and interventional research.

Future studies should focus on evaluating the effectiveness of these approaches and developing evidence-based guidelines to enhance surgeon well-being and career longevity.

Ethical Considerations

All participants received an informed consent form outlining the study's objectives, the voluntary nature of participation, and the confidentiality of their data before beginning the survey.

Funding/Support

This study received no specific funding.

Conflict of Interest/Disclosure statement

The authors have no conflicts of interest to declare.

CRediT authorship contribution statement

Stefano Restaino: Writing – review & editing, Visualization, Validation, Project administration, Investigation, Data curation, Conceptualization. **Nicoletta Crivellaro:** Writing – original draft, Formal analysis, Data curation. **Federico Paparcura:** Resources, Formal analysis, Data curation. **Gianluca Pellino:** Validation, Supervision, Data curation. **Mauro Podda:** Methodology, Formal analysis, Data curation. **Alice Poli:** Visualization, Validation. **Giulia Pellecchia:** Visualization, Resources. **Martina Arcieri:** Methodology, Investigation, Data curation. **Federica Perelli:** Project administration, Methodology, Formal analysis. **Marco D'Indinosante:** Resources, Data curation. **Benedetto Ielpo:** Visualization, Supervision. **Marcello Di Martino:** Methodology, Investigation, Data curation. **Giovanni Scambia:** Validation, Supervision. **Lorenza Driul:** Visualization, Validation. **Giuseppe Vizzielli:** Writing – review & editing, Visualization, Validation, Supervision.

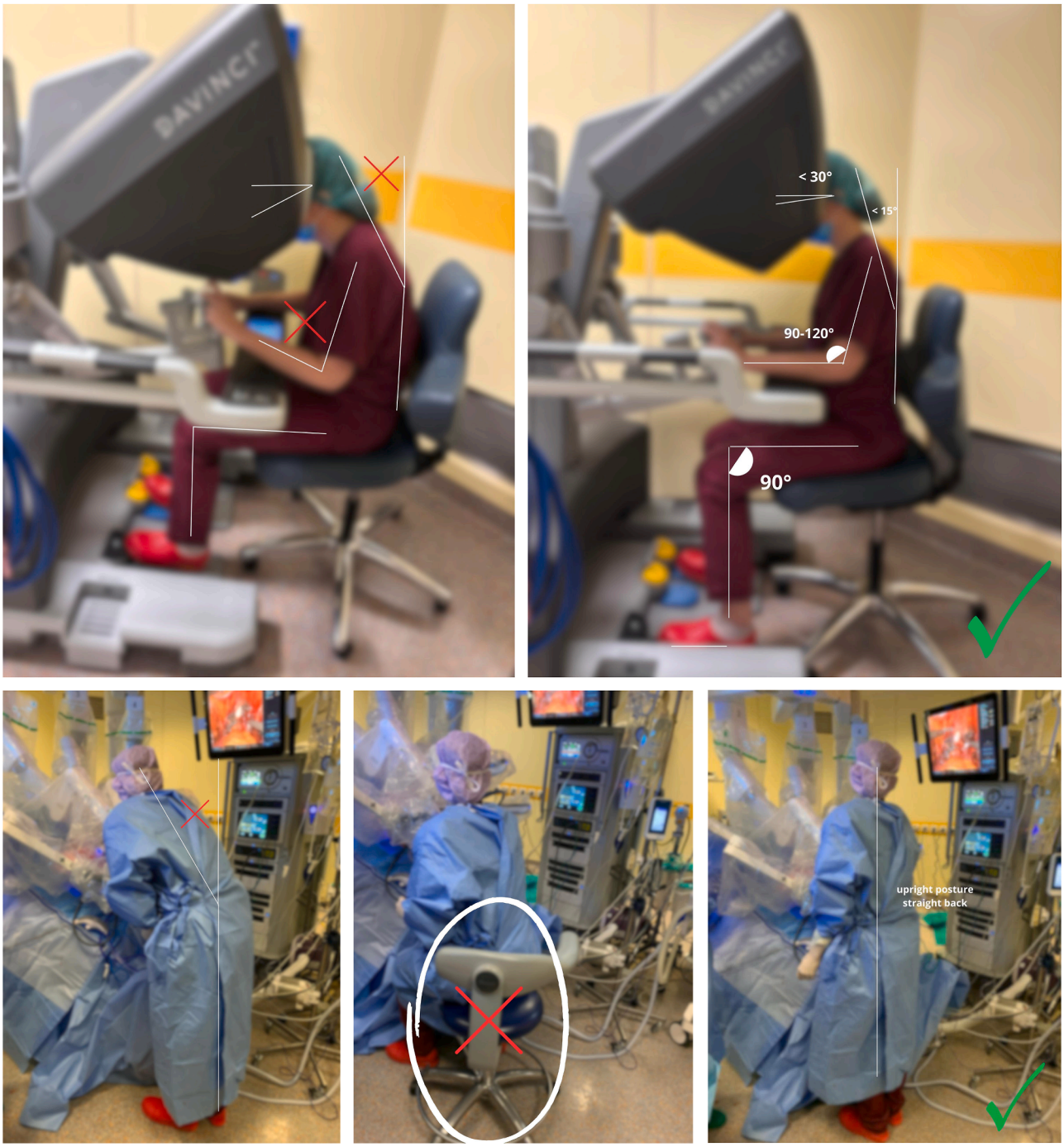

Figure 3. Main postural errors in robotic surgery.

Francesco Pata: Writing – review & editing, Visualization, Validation, Supervision.

References

1. Hetzler PT, Katz RD. A primer on optimizing ergonomics in the operating room. *JAMA Surg*. 2024;159:1337–1338.
2. Epstein S, Sparer EH, Tran BN, et al. Prevalence of work-related musculoskeletal disorders among surgeons and interventionalists: a systematic review and meta-analysis. *JAMA Surg*. 2018;153:e174947.
3. Pérez-Salazar MJ, Caballero D, Sánchez-Margallo JA, Sánchez-Margallo FM. Comparative Study of ergonomics in conventional and robotic-assisted laparoscopic surgery. *Sensors (Basel)*. 2024;24:3840.
4. Gianikellis K, Skiadopoulos A, Palma CE, Sanchez-Margallo FM, Carrasco JBP, Sanchez-Margallo JAA. A method to assess upper-body postural variability in laparoscopic surgery. In: *Proceedings of the 5th IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics*. Sao Paulo, Brazil. Piscataway, NJ: IEEE; 2014:76–81.
5. Wee IJY, Kuo LJ, Ngu JCY. A systematic review of the true benefit of robotic surgery: ergonomic. *Int J Med Robot Comput Assist Surg*. 2020;16:e2113.
6. Szeto GPY, Poon JTC, Law WL. A comparison of surgeon's postural muscle activity during robotic-assisted and laparoscopic rectal surgery. *J Robot Surg*. 2013;7:305–308.

7. Dalsgaard T, Jensen MD, Hartwell D, Mosgaard BJ, Jørgensen A, Jensen BR. Robotic surgery is less physically demanding than laparoscopic surgery: paired cross-sectional study. *Ann Surg*. 2020;271:106–113.
8. Lee GI, Lee MR, Green I, Allaf M, Marohn MR. Surgeons' physical discomfort and symptoms during robotic surgery: a comprehensive ergonomic survey study. *Surg Endosc*. 2017;31:1697–1706.
9. Division of Education & Surgical Ergonomics Committee. *Surgical ergonomics recommendations*. American College of Surgeons; 2024. https://www.facs.org/media/cezf1xvo/surgicalergonomicsrecommendations.pdf. Accessed April 12, 2024.
10. Dairywala M, Gupta S, Salna M, Nguyen T. Surgeon strength: ergonomics and strength training in cardiothoracic surgery. *Semin Thorac Cardiovasc Surg*. 2022;34:1220–1229.
11. Fisher SM, Teven CM, Song DH. Ergonomics in the operating room: the cervicospinal health of today's surgeons. *Plast Reconstr Surg*. 2018;142:1380–1387.
12. Kroth PJ, Morioka-Douglas N, Veres S, et al. Association of electronic health record design and use factors with clinician stress and burnout. *JAMA Netw Open*. 2019;2:e199609.
13. Koshy K, Syed H, Luckiewicz A, Alsoof D, Koshy G, Harry L. Interventions to improve ergonomics in the operating theatre: a systematic review of ergonomics training and intra-operative microbreaks. *Ann Med Surg (Lond)*. 2020;55:135–142.
14. Eysenbach G. Improving the quality of web surveys: the checklist for reporting results of internet E-Surveys (CHERRIES). *J Med Internet Res*. 2004;6:e34.
15. Xepoleas MD, Munabi NCO, Auslander A, Magee WP, Yao CA. The experiences of female surgeons around the world: a scoping review. *Hum Resour Health*. 2020;18:80.
16. Restaino S, D'Indinosante M, Perelli F, Arcieri M, Cherchi V, Petrillo M, et al. Ergonomics in the operating room and surgical training: a survey on the Italian scenario. *Front Public Health*. 2024;12:1417250.
17. Park A, Lee G, Seagull FJ, Meenaghan N, Dexter D. Patients benefit while surgeons suffer: an impending epidemic. *J Am Coll Surg*. 2010;210:306–313.
18. Tavakkol R, Karimi A, Hassanipour S, Gharahzadeh A, Fayz A. A multidisciplinary focus review of musculoskeletal disorders among operating room personnel. *J Multidiscip Healthc*. 2020;13:735–741.
19. Jacquier-Bret J, Gorce P. Prevalence of body area work-related musculoskeletal disorders among healthcare professionals: a systematic review. *Int J Environ Res Public Health*. 2023;20:841.
20. Michael S, Mintz Y, Brodie R, Assalia A. Minimally invasive surgery and the risk of work-related musculoskeletal disorders: results of a survey among Israeli surgeons and review of the literature. *Work*. 2022;71:779–785.
21. Franasiak J, Craven R, Mosaly P, Gehrig PA. Feasibility and acceptance of a robotic surgery ergonomic training program. *JSLS*. 2014;18:e2014.00166.