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Assistant ergonomics in robotic surgery

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Abstract

Importance

The use of robotic platforms in surgery has markedly increased over the past two decades, becoming the standard of care for several procedures in different specialties. Although the benefits of robotic surgery for patients are well established, the adoption of minimally invasive techniques has introduced new ergonomic challenges for both console and assistant surgeons. While ergonomics in console surgeons have been extensively investigated, data regarding the working conditions of table assistants remain limited.

Objective

This study aimed primarily to obtain a preliminary understanding of the ergonomic conditions experienced by surgical assistants during robotic procedures. The secondary aim was to explore the psychological implications associated with the physical strain of surgical assistance. Finally, the study sought to identify potential factors that may mitigate ergonomic discomfort among assistants.

Design, Setting, and Participants

An anonymous questionnaire was developed using the Google Forms platform. The survey included sections on participants' demographics, operating room setup, musculoskeletal symptoms, and surgical workload. Data were collected between May and August 2025.

Results

A total of 122 international participants, including residents and attending surgeons from various specialties, completed the survey. Among them, 54.1% assisted in more than two procedures per day, and 96% reported procedures lasting over 90 minutes. 71 participants used more than two monitors, and an equal number alternated between sitting and standing positions. Pain related to surgical activity was reported by 92 respondents, though medication was required in only 24.6% of cases. The most affected areas were the neck (74.6%), lower back (66.4%), and upper back (51.6%).

Multivariate analysis showed that greater height and larger glove size were associated with surgery-related pain (OR 1.13, p=0.05); conversely, univariate analyses showed that larger glove size was significantly associated with a lower likelihood of surgery-related pain (OR 0.40, 95% CI 0.17–0.86; p=0.025) and the use of more than two monitors was associated with reduce pain.

Regarding perceived comfort, univariate analysis showed that female sex was associated with lower comfort scores (β −0.61, 95% CI −1.1 to −0.10; p=0.020), while larger glove size was associated with higher comfort (β 0.46, 95% CI 0.04–0.88; p=0.030). According to the NASA-TLX assessment, the median mental and physical effort was 70 (IQR 50–80), temporal demand 70 (IQR 50–80), success rate 85 (65–90), overall effort 70 (60–85), and frustration level 50 (20–70).

Conclusion

In conclusion, table-side assistance in robotic surgery is associated with significant pain and discomfort. Increased height and decreased glove size were identified as predictors of surgery-related discomfort. These findings underscore the need for improved ergonomic standardisation and greater awareness among surgical teams to enhance safety and performance in the robotic operating room.

1. INTRODUCTION

The use of robotic platforms in surgery dates back to approximately 40 years ago, however, the number of robotic procedures has significantly increased over the past two decades, becoming the standard of care for numerous procedures(1)(2). Although the benefits of robotic surgery for patients are well established, the adoption of minimally invasive techniques has introduced new ergonomic challenges for both console and assistant surgeons: instrument handling, monitor positioning, bed hight, console setups (3,4).

It's commonly believed that robotic surgery systems provide surgeons with an ergonomically optimal working environment. Nonetheless, as stated by Lee et al(4), the 56.1% of the surgeons involved reported physical discomfort during or after a robotic procedure, despite the ergonomics adjustments available for the console surgeon.

While the ergonomics of console surgeons have been extensively investigated, data regarding the working conditions of table assistants remain limited.

The bed-table assistant encounters ergonomic challenges comparable to those faced by the laparoscopic surgeon(5), particularly regarding table and monitor placement, instrument handling, and the maintenance of sustained, non-neutral postures. In this setting, work-related musculoskeletal disorders are highly prevalent, with reported rates ranging from 47% to 87%. These conditions, including lower back pain, cervical pain, carpal tunnel syndrome, intervertebral disc disorders, headache, lateral epicondylitis, and shoulder muscle spasm, are primarily attributable to prolonged standing, inadequate ergonomic positioning, and repetitive movements involving rigid surgical instruments(6–12).

These factors should be interpreted within the context of an operative environment characterized by the presence of robotic arms within the surgical field, which may further increase ergonomic constraints and introduce a potential risk of instrument–robot or operator–robot collisions.

In this regard, a survey conducted within the Italian laparoscopic community reported that 98.7% of participants experienced physical discomfort during abdominal laparoscopic procedures, frequently culminating in musculoskeletal pain(13). Considering these findings and the paucity of data addressing the ergonomic conditions of the table assistant, further dedicated investigations are warranted to better characterize occupational risk and to inform preventive strategies.

This study aimed to obtain a preliminary understanding of the ergonomic conditions experienced by surgical assistants during robotic procedures. The secondary aim was to explore the psychological implications associated with the physical strain of surgical assistance. Finally, the study sought to identify potential factors that may mitigate ergonomic discomfort among assistants.

2. MATERIAL AND METHODS

2.1 Study Design

An anonymous electronic questionnaire was developed using Google Forms and disseminated internationally via e-mail.

The study protocol was approved by the Ethisch Comité AZORG (approval number: 2025/053). The study was conducted in accordance with the principles of the Declaration of Helsinki, Good Clinical Practice guidelines, and the Checklist for Reporting of Survey Studies (CROSS) methodology.

Participation was voluntary and anonymous. All participants provided informed electronic consent prior to questionnaire completion. Survey responses were anonymized and securely stored to ensure confidentiality and data protection.

2.2 Study Population

Eligible participants included consultant surgeons, fellows, and residents from different surgical specialties (urology, general surgery, gynaecology, paediatric surgery, vascular surgery and transplant surgery) involved in robotic abdominal surgery, with at least one year of experience as bedside assistants during robotic procedures. Limited robotic experience as bedside assistant and specialties involving other regions than abdomen and retroperitoneum were exclusion criteria.

2.3 Data Collection

The questionnaire consisted of three main sections. The first section collected demographic and professional data, including sex, height, weight, glove size, hand dominance (right- or left-handed), professional status (consultant or resident), and year of residency training.

The second section focused on ergonomic and environmental factors related to robotic bedside assistance: duration of robotic procedures, number of procedures performed per day, working position during assistance, and number and positioning of operative monitors.

The third section investigated physical discomfort and psychological workload. It included general questions regarding the onset and anatomical distribution of symptoms, as well as the use of medications for symptom management. In addition, validated assessment tools were administered. The Nordic Musculoskeletal Questionnaire (NMQ) was used to assess musculoskeletal symptoms by evaluating the presence of pain or discomfort during the previous 12 months and the previous 7 days across nine anatomical regions: neck, shoulders, elbows, wrists/hands, upper back, lower back,

hips/thighs, knees, and ankles/feet. Perceived workload was assessed using the NASA Task Load Index (NASA-TLX).

The primary study outcomes included the prevalence and severity of musculoskeletal discomfort among bedside assistants, self-reported physical and mental fatigue during robotic procedures, and the identification of ergonomic risk factors, including working posture, monitor positioning and number, and operating room setup.

2.4 Statistical Analysis

Descriptive statistics were used to summarize demographic characteristics and survey responses. Continuous variables were reported as mean ± standard deviation or median with interquartile range, according to data distribution, whereas categorical variables were expressed as frequencies and percentages. Associations between ergonomic factors and reported physical or psychological symptoms were explored using correlation analyses and comparative statistical tests, as appropriate.

Statistical analyses were conducted in R version 4.5.0 (R Foundation for Statistical Computing), with a two-sided P value < 0.05 taken to indicate statistical significance.

3. RESULTS

A total of 122 participants completed the survey, including both residents (45.9%) and consultants (54.1%) from different surgical specialties, predominantly urology (67.2%; Table 1). The cohort was mainly composed of male respondents (65.6%), with a median age of 32 years (IQR 29–36). Median height and weight were 175 cm (IQR 168–181) and 75 kg (IQR 64–83), respectively, with a median glove size of 7 (IQR 6.5–7.5).

Table 1
Baseline characteristics, operative workload, ergonomic setup, and workload scores

Variable	Overall (n = 122)
Demographics	
Age, years	32 (29–36)
Male sex	80 (65.6%)
Female sex	40 (32.8%)
Height, cm	175 (168–181)
Weight, kg	75 (64–83)
Glove size	7.0 (6.5–7.5)
Right-handed	115 (94.3%)
Professional characteristics	
Consultant	66 (54.1%)
Resident	56 (45.9%)
Urology	82 (67.2%)
General surgery	33 (27.0%)
Other specialties	7 (5.8%)
Operative workload	
0–1 procedures/day	55 (45.1%)
2–5 procedures/day	61 (50.0%)
> 5 procedures/day	5 (4.1%)
Procedure duration 90–180 min	77 (63.1%)
Procedure duration > 180 min	40 (32.8%)
Assistant for entire procedure	103 (84.4%)
No intraoperative breaks	100 (82.0%)
Ergonomic setup	
Sitting	28 (23.0%)
Standing	23 (18.9%)
Both	71 (58.2%)

Variable	Overall (n = 122)
1 monitor	51 (41.8%)
2 monitors	59 (48.4%)
> 2 monitors	12 (9.8%)
Monitor position (both)	63 (51.6%)
Collisions with robotic arms	112 (91.8%)
Pain outcomes	
Surgery-related pain	92 (75.4%)
Use of medication	30 (24.6%)
Neck pain (12 months)	91 (74.6%)
Lower back pain (12 months)	81 (66.4%)
Upper back pain (12 months)	59 (48.4%)
NASA-TLX workload and comfort scores	
Comfort (0–10 scale)	4 (4–5)
Mental demand (0–100 scale)	70 (50–80)
Physical demand (0–100 scale)	70 (50–80)
Temporal demand (0–100 scale)	70 (50–80)
Effort (0–100 scale)	70 (60–85)
Frustration (0–100 scale)	50 (20–70)

3.1 Operative workload and intraoperative setup

Most participants reported a high operative workload, with 50.0% assisting in 2–5 procedures per day and 4.1% in more than five procedures daily. Procedures typically lasted between 90 and 180 minutes (63.1%), while 32.8% exceeded 180 minutes. Most assistants were involved throughout the entire procedure (84.4%), and intraoperative breaks were uncommon (82.0% reported no breaks).

Regarding ergonomic setup, 58.2% of respondents alternated between sitting and standing positions, while 23.0% worked predominantly seated and 18.9% standing. Most participants used one (41.8%) or two monitors (48.4%), with only 9.8% reporting the use of more than two monitors. Monitor positioning was most commonly both frontal and lateral (51.6%), although 65.6% reported only occasional comfort with monitor placement. Collisions between robotic arms and the assistant were reported by 91.8% of participants.

3.2 Prevalence and characteristics of surgery-related pain

Overall, 75.4% of respondents reported surgery-related pain, with symptoms occurring most frequently on a monthly (46.7%) or weekly basis (28.7%). Pain was reported both during and after surgery in 40.2% of cases. Analgesic use was required by 24.6% of participants.

Musculoskeletal symptoms were predominantly localised to the neck (74.6%), lower back (66.4%), and upper back (48.4%). Shoulder pain was also frequent, affecting over 60% of respondents when considering unilateral and bilateral involvement. In contrast, elbow, hip, knee, and ankle pain were less commonly reported (Fig. 1).

3.3 Work environment and perceived comfort

Participants reported suboptimal working conditions, with only 9.8% declaring to always be in a comfortable position, whereas 82.0% reported being comfortable only intermittently. Spatial constraints were common, with 52.5% reporting limited space only sometimes and 32.0% consistently perceiving inadequate space. Communication with the console surgeon was judged adequate in 51.6% of cases but only occasionally adequate in 42.6%.

The median overall comfort score during robotic assistance was low, at 4 (IQR 4–5) on a 0–10 scale. According to the NASA-TLX assessment, both mental and physical workload were high, with median scores of 70 (IQR 50–80) for mental effort and 70 (IQR 50–80) for physical effort. Temporal demand was similarly elevated (median 70, IQR 50–80), while perceived performance remained high (median 85, IQR 65–90). Frustration levels were moderate (median 50, IQR 20–70).

3.4 Factors associated with surgery-related pain and comfort

At univariate analysis, larger glove size was significantly associated with a lower likelihood of surgery-related pain (OR 0.40, 95% CI 0.17–0.86; p = 0.025), while the use of more than two monitors was also associated with reduced pain (OR 0.20, 95% CI 0.05–0.73; p = 0.016). In the multivariable model, greater height (OR 1.13, 95% CI 1.01–1.29; p = 0.050) and smaller glove size (OR 0.07, 95% CI 0.00–0.70; p = 0.034) were independently associated with surgery-related pain (Table 2**)**.

Table 2
Univariate and multivariable logistic regression analysis of predictors of surgery-related pain.

Variable	Univariate analysis OR (95% CI)	P value	Multivariable analysis OR (95% CI)	P value
Height (cm)	0.98 (0.93–1.03)	0.40	1.13 (1.01–1.29)	**0.05**
Weight (kg)	0.97 (0.94–1.01)	0.12	0.98 (0.90–1.06)	0.60
Female sex	2.29 (0.89–6.69)	0.10	0.49 (0.06–3.87)	0.50
Glove size	0.40 (0.17–0.86)	**0.025**	0.07 (0.00–0.70)	**0.034**
2–5 procedures/day	1.82 (0.77–4.45)	0.20	2.17 (0.73–6.80)	0.20
> 5 procedures/day	0.27 (0.03–1.75)	0.20	0.35 (0.03–3.94)	0.40
Procedure > 180 min	0.75 (0.04–5.86)	0.80	2.14 (0.65–7.87)	0.20
> 2 monitors	0.20 (0.05–0.73)	**0.016**	0.22 (0.03–1.86)	0.20
Sitting position	2.35 (0.79–8.76)	0.20	2.92 (0.78–13.4)	0.13
Standing position	1.11 (0.40–3.44)	0.80	1.09 (0.25–5.10)	0.90

Regarding perceived comfort, univariate analysis showed that female sex was associated with lower comfort scores (β − 0.61, 95% CI − 1.1 to − 0.10; p = 0.020), while larger glove size was associated with higher comfort (β 0.46, 95% CI 0.04–0.88; p = 0.030). However, in multivariable analysis, no variables were independently associated with comfort (Table 3).

Table 3
Univariate and multivariable linear regression analysis of predictors of comfort (0–10 scale).

Variable	Univariate analysis β (95% CI)	P value	Multivariable analysis β (95% CI)	P value
Height (cm)	0.02 (0.00–0.05)	0.10	-0.02 (-0.08–0.04)	0.60
Weight (kg)	0.02 (0.00–0.04)	0.053	0.01 (-0.03–0.05)	0.70
Female sex	-0.61 (-1.10 to -0.10)	**0.020**	-0.47 (-1.50–0.57)	0.40
Glove size	0.46 (0.04–0.88)	**0.030**	0.16 (-0.89–1.20)	0.80
2–5 procedures/day	-0.39 (-0.89–0.11)	0.12	-0.50 (-1.10–0.09)	0.095
> 5 procedures/day	0.39 (-0.87–1.70)	0.50	0.32 (-1.20–1.80)	0.70
> 2 monitors	0.39 (-0.48–1.30)	0.40	0.39 (-0.82–1.60)	0.50
Sitting position	0.11 (-0.51–0.72)	0.70	0.16 (-0.52–0.84)	0.60
Standing position	0.04 (-0.62–0.70)	0.90	-0.06 (-0.88–0.76)	0.90

4. DISCUSSION

Although the benefits of robotic surgery for patients are well established, the widespread adoption of minimally invasive techniques has introduced new ergonomic challenges, particularly for the bedside assistants, who operate in a dynamic and spatially constrained environment that may expose them to musculoskeletal stressors. This survey investigates the prevalence, anatomical distribution, and procedural correlates of self-reported physical discomfort among bedside assistants. The findings aim to support the development of targeted ergonomic interventions and evidence-based strategies to improve occupational safety and surgical team performance.

Of the 122 questionnaires collected, 96% of participants reported involvement in procedures lasting longer than 90 minutes, thereby implying prolonged exposure to constrained postures and repetitive, stereotyped movements without adequate rest intervals. Surgery-related pain was reported by 75.4% of respondents; however, pharmacological treatment was required in only 24.6% of cases. These findings are slightly lower than those reported in a survey conducted among laparoscopic surgeons (13), in which more than 98% of participants experienced physical discomfort. This comparison suggests that the transition from assisting in conventional laparoscopic procedures to robotic surgery may be associated with a reduction in perceived physical strain. Similarly, the need to adopt pharmacological or alternative strategies to alleviate pain, such as compression stockings, ankle braces, transdermal patches, orthopaedic insoles, lumbar supports, or physio kinesitherapy, appears to be lower in the robotic setting.

Analysis of the distribution of musculoskeletal symptoms (Fig. 1) revealed that 74.6% of cases were primarily localized to the cervical region, followed by the lower back (66.4%) and upper back (48.4%).

Shoulder pain was also highly prevalent, affecting more than 60% of respondents when both unilateral and bilateral involvement were considered. Our findings are fully consistent with those reported by Lee et al.(4), suggesting that, despite variations in surgical posture, the anatomical regions most affected by discomfort remain largely the same. This highlights the need for interventions and structured educational programs aimed at improving surgeons' posture and occupational well-being. Notably, there is currently a lack of comprehensive, standardized guidelines addressing optimal positioning and operating room setup in robotic surgery. However, practical ergonomic recommendations have been proposed in the literature, particularly in the context of urological laparoscopic surgery, as described by Gabrielson et al (14) and Tetteh et al. (15). Key strategies to improve surgeon comfort include maintaining a neutral posture, characterized by limited neck flexion (< 25°(14) or < 30°(15)), relaxed shoulders, and elbow angles between 90° and 120°, as well as optimizing operating table height (ideally at or slightly below elbow level) to reduce muscular strain. Laparoscopic operating rooms should be equipped with at least two 24-inch monitors, properly positioned (directly in front of the surgeon, at a distance of 80–120 cm(14) or 140–305 cm(15) and slightly below eye level) to minimize neck and eye fatigue. In line with this, univariate analysis from our study demonstrated that the use of more than two monitors was associated with a significant reduction in pain (OR 0.20, 95% CI 0.05–0.73; p = 0.016).

Additional measures include the use of intraoperative microbreaks (reported only by the 18% of our participants) and stretching exercises, which have been shown to reduce fatigue and improve performance, as well as encouraging regular physical activity to mitigate musculoskeletal discomfort.

Increased awareness and formal training in ergonomics are strongly advocated, given their demonstrated role in reducing work-related injuries and improving long-term surgeon well-being. Among the proposed interventions, the Alexander Technique(16) has emerged as a promising approach in the field of minimally invasive surgery. This educational method aims to enhance postural awareness and reduce excessive muscular tension by helping individuals recognize and modify habitual patterns of inefficient posture.

Participants reported suboptimal working conditions, with only 9.8% indicating that they were always able to maintain a comfortable posture, while 82.0% reported comfort only intermittently. Limited operative space was frequently described, with 32% of respondents reporting inadequate working room during surgical activity. Moreover, collisions between robotic arms and the assistant were reported by 91.8% of participants. Interactions with robotic arms often force the assistant to adopt compensatory and ergonomically unfavourable positions to maintain visualization of the surgical field and minimize interference with the robotic system. These sustained postures, combined with prolonged muscular contraction, may lead to the onset of musculoskeletal strain.

Pain symptoms most frequently occurred on a monthly (46.7%) or weekly (28.7%) basis. Pain was reported both intraoperatively and postoperatively in 40.2% of cases. Despite the high prevalence of musculoskeletal pain, only 24.6% of respondents reported the use of pain medications, consistent with findings reported in a recent systematic review (17). Among the most reported strategies for managing

pain, 32.3% of participants used nonsteroidal anti-inflammatory drugs (NSAIDs), 19.4% used paracetamol, and only 3.2% resorted to physiotherapy. However, physical exercise, particularly when aimed at muscular strengthening, may substantially improve symptomatology. Indeed, physical activity has been shown to act as a protective factor against pain symptoms, comparable to maintaining a normal body mass index (BMI) within the healthy range (18).

However, the operating room setup is not the only factor to be considered. Individual anthropometric characteristics also appear to play a significant role in intraoperative and postoperative surgeon discomfort. In univariate analysis, larger glove size was associated with a significantly lower likelihood of surgery-related pain. In the multivariable model, greater height emerged as an independent risk factor, whereas larger glove size remained significantly protective. These findings suggest that anthropometric factors may substantially influence ergonomic strain, with smaller hand size potentially predisposing surgeons to suboptimal instrument handling and increased musculoskeletal load, consistent with previous reports. This observation may be interpreted in light of the historical predominance of men in the surgical workforce, whereby the design and development of surgical instruments have traditionally been based on anthropometric characteristics representative of larger hand dimensions. This paradigm warrants critical re-evaluation and highlights the need for further research and innovation in surgical instrument design to ensure their adaptability and usability across individuals with different physical characteristic, represented in the contemporary surgical workforce(19).

Attention to operating room ergonomics extends beyond the mitigation of musculoskeletal discomfort among surgical personnel by reducing physical strain, it may also decrease fatigue, thereby enhancing operative performance, shortening procedure duration, and improving overall surgical efficiency(20).

Intraoperative stress represents a significant determinant of surgeon well-being and a contributing factor to burnout and its accurate assessment is essential for optimizing both surgeon performance and patient outcomes; however, physiological stress responses during surgery are highly variable and may be difficult to quantify and interpret reliably(20). In our cohort, assisting during robotic procedures was associated with substantial physical, mental, and temporal demands, with a median score of 70 (IQR 50–80) on a 0–100 scale according to the NASA Task Load Index (NASA-TLX). Conversely, frustration levels were moderate (median 50, IQR 20–70). Its applicability and precision in surgical settings has been further enhanced by an innovative study that led to the development and validation of a modified version, the SURG-TLX(21), specifically tailored to account for the unique demands of the surgical field and operating room environment. This reflects a growing emphasis on ergonomics and on the physical and mental well-being of surgeons, factors that have historically been considered secondary to technical surgical performance. Further research is warranted to better optimize operating room design and to enhance ergonomics-focused training among healthcare professionals, with the aim of reducing discomfort and strain associated with clinical practice.

This study has several limitations that should be acknowledged. First, its cross-sectional design and reliance on self-reported data may introduce reporting bias, potentially affecting the accuracy of the

findings and the voluntary nature of participation may have led to selection bias, with individuals experiencing greater discomfort being more likely to respond.

Second, the absence of objective ergonomic or physiological measurements (e.g., motion analysis, electromyography, or stress biomarkers) limits the ability to correlate perceived workload and discomfort with quantifiable physical strain. Third, the heterogeneity of participants in terms of surgical specialty, experience, and operating room environments may have introduced confounding variables that were not fully controlled. Additionally, the lack of standardization in robotic platforms, operative setups, and assistant roles across centres may limit the generalizability of the results. The sample size, although relatively large for a survey-based study, remains limited and may reduce the statistical power to detect significant associations, particularly in multivariable analyses. Finally, the study design does not allow for causal inference, and longitudinal studies are warranted to better assess the long-term impact of ergonomic strain on musculoskeletal health and surgical performance.

Despite these limitations, this study provides valuable insights into the key factors that should be addressed to optimize the operating room environment. In particular, it highlights the importance of aspects that are often considered secondary, yet may substantially contribute to surgical performance by reducing physical stress, discomfort, and potentially even operative time. Increasing attention is being directed toward workplace well-being across all professional fields, and the operating room should not represent an exception.

Future studies are needed to further investigate these ergonomic issues and to provide evidence-based recommendations aimed at standardizing the robotic operating room environment through structured protocols. Developing standardized guidelines may help optimize workflow, reduce physical strain, and improve both surgeon well-being and procedural efficiency.

5. CONCLUSIONS

In conclusion, table-side assistance in robotic surgery is associated with significant pain and discomfort. Increased height was identified as predictors of surgery-related discomfort, while increased glove size was associated with increased comfort. These findings underscore the need for improved ergonomic standardisation and greater awareness among surgical teams to enhance safety and performance in the robotic operating room.

Declarations

Author contibutions

A.N.-M., ans S.T. contributed to the conceptualization of the study. S.T.., together with A.N.M. coordinated the overall conduct of the study. S.T., A.N.-M., A.G. and A.B. were responsible for drafting the manuscript and contributed to data curation and data presentation, with A.B. specifically responsible for the graphical components. Data extraction was performed by A.G. and A.B.. The manuscript was

critically reviewed and revised by E.B., M.d.A., F.P., A.G., F.P., C.B., N.R., V.C., E.P., P.P., L.B., R.S., G.D.N., R.D.G., A.M. All authors reviewed and approved the final version of the manuscript.

Following completion of the manuscript, generative artificial intelligence was used exclusively to improve English grammar and language. The authors reviewed and edited all AI-generated suggestions and take full responsibility for the final content of the manuscript.

Declaration of conflicting interests

The manufacturer did not have any role in the study design, data collection, data analysis, data interpretation, or manuscript preparation, and only provided technical assistance in response to specific technical queries. The authors declare no conflicts of interest.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethisch Comité AZORG (approval number: 2025/053).

References

1. Morrell ALG, Morrell-Junior AC, Morrell AG, Mendes JMF, Tustumi F, De-Oliveira-E-Silva LG, et al. The history of robotic surgery and its evolution: when illusion becomes reality. Rev Col Bras Cir. 2021;48:e20202798. doi:10.1590/0100-6991e-20202798
2. Oberlin DT, Flum AS, Lai JD, Meeks JJ. The effect of minimally invasive prostatectomy on practice patterns of American urologists. Urologic Oncology: Seminars and Original Investigations. giugno 2016;34(6):255.e1-255.e5. doi:10.1016/j.urolonc.2016.01.008
3. Matern U. Ergonomic deficiencies in the operating room: Examples from minimally invasive surgery. Work. 2009;33(2):165–8. doi:10.3233/WOR-2009-0862
4. 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. aprile 2017;31(4):1697–706. doi:10.1007/s00464-016-5160-y
5. Van Der Schatte Olivier RH, Van'T Hullenaar CDP, Ruurda JP, Broeders IAMJ. Ergonomics, user comfort, and performance in standard and robot-assisted laparoscopic surgery. Surg Endosc. giugno 2009;23(6):1365–71. doi:10.1007/s00464-008-0184-6

6. Park A, Lee G, Seagull JF, Meenaghan N, Dexter D. Patients Benefit While Surgeons Suffer: An Impending Epidemic. Journal of the American College of Surgeons. marzo 2010;210(3):306–13. doi:10.1016/j.jamcollsurg.2009.10.017
7. Babar-Craig H, Banfield G, Knight J. Prevalence of back and neck pain amongst ENT consultants: national survey. J Laryngol Otol. dicembre 2003;117(12):979–82. doi:10.1258/002221503322683885
8. Bolduc-Bégin J, Prince F, Christopoulos A, Ayad T. Work-related musculoskeletal symptoms amongst Otolaryngologists and Head and Neck surgeons in Canada. Eur Arch Otorhinolaryngol. gennaio 2018;275(1):261–7. doi:10.1007/s00405-017-4787-1
9. Rimmer J, Amin M, Fokkens WJ, Lund VJ. Endoscopic sinus surgery and musculoskeletal symptoms. Rhin. 1 giugno 2016;54(2):105–10. doi:10.4193/Rhino15.217
10. Little RM, Deal AM, Zanation AM, McKinney K, Senior BA, Ebert CS. Occupational hazards of endoscopic surgery. Int Forum Allergy Rhinol. maggio 2012;2(3):212–6. doi:10.1002/alr.20108
11. Alleblas CCJ, De Man AM, Van Den Haak L, Vierhout ME, Jansen FW, Nieboer TE. Prevalence of Musculoskeletal Disorders Among Surgeons Performing Minimally Invasive Surgery: A Systematic Review. Annals of Surgery. dicembre 2017;266(6):905–20. doi:10.1097/SLA.0000000000002223
12. Alqahtani SM, Alzahrani MM, Tanzer M. Adult Reconstructive Surgery: A High-Risk Profession for Work-Related Injuries. The Journal of Arthroplasty. giugno 2016;31(6):1194–8. doi:10.1016/j.arth.2015.12.025
13. 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. 7 agosto 2024;12:1417250. doi:10.3389/fpubh.2024.1417250
14. Gabrielson AT, Clifton MM, Pavlovich CP, Biles MJ, Huang M, Agnew J, et al. Surgical ergonomics for urologists: a practical guide. Nat Rev Urol. marzo 2021;18(3):160–9. doi:10.1038/s41585-020-00414-4
15. Tetteh E, Wang T, Kim JY, Smith T, Norasi H, Van Straaten MG, et al. Optimizing ergonomics during open, laparoscopic, and robotic-assisted surgery: A review of surgical ergonomics literature and development of educational illustrations. The American Journal of Surgery. settembre 2024;235:115551. doi:10.1016/j.amjsurg.2023.11.005
16. Reddy PP, Reddy TP, Roig-Francoli J, Cone L, Sivan B, DeFoor WR, et al. The Impact of the Alexander Technique on Improving Posture and Surgical Ergonomics During Minimally Invasive Surgery: Pilot Study. Journal of Urology. ottobre 2011;186(4S):1658–62. doi:10.1016/j.juro.2011.04.013
17. Stucky CCH, Cromwell KD, Voss RK, Chiang YJ, Woodman K, Lee JE, et al. Surgeon symptoms, strain, and selections: Systematic review and meta-analysis of surgical ergonomics. Annals of Medicine and Surgery. marzo 2018;27:1–8. doi:10.1016/j.amsu.2017.12.013
18. Lloyd GL, Chung ASJ, Steinberg S, Sawyer M, Williams DH, Overbey D. Is Your Career Hurting You? The Ergonomic Consequences of Surgery in 701 Urologists Worldwide. Journal of Endourology. dicembre 2019;33(12):1037–42. doi:10.1089/end.2019.0150

19. Ogawa M, Miyoshi N, Tamura S, Masuda M, Matuyama K, Matsuki T, et al. Ergonomic and sustainable posture for gynecological laparoscopic surgeons determined based on images analyzed using artificial intelligence. Biomed Rep. 23 settembre 2024;21(6):174. doi:10.3892/br.2024.1862
20. Budden AK, Henry A, Wakefield CE, Abbott JA. Surgeon stress, anxiety, and workload: a descriptive study of participant reported responses to fundamentals of laparoscopic surgery exercises. Surg Endosc. novembre 2024;38(11):6518–26. doi:10.1007/s00464-024-11238-3
21. Wilson MR, Poolton JM, Malhotra N, Ngo K, Bright E, Masters RSW. Development and Validation of a Surgical Workload Measure: The Surgery Task Load Index (SURG-TLX). World j surg. settembre 2011;35(9):1961–9. doi:10.1007/s00268-011-1141-4

Figures

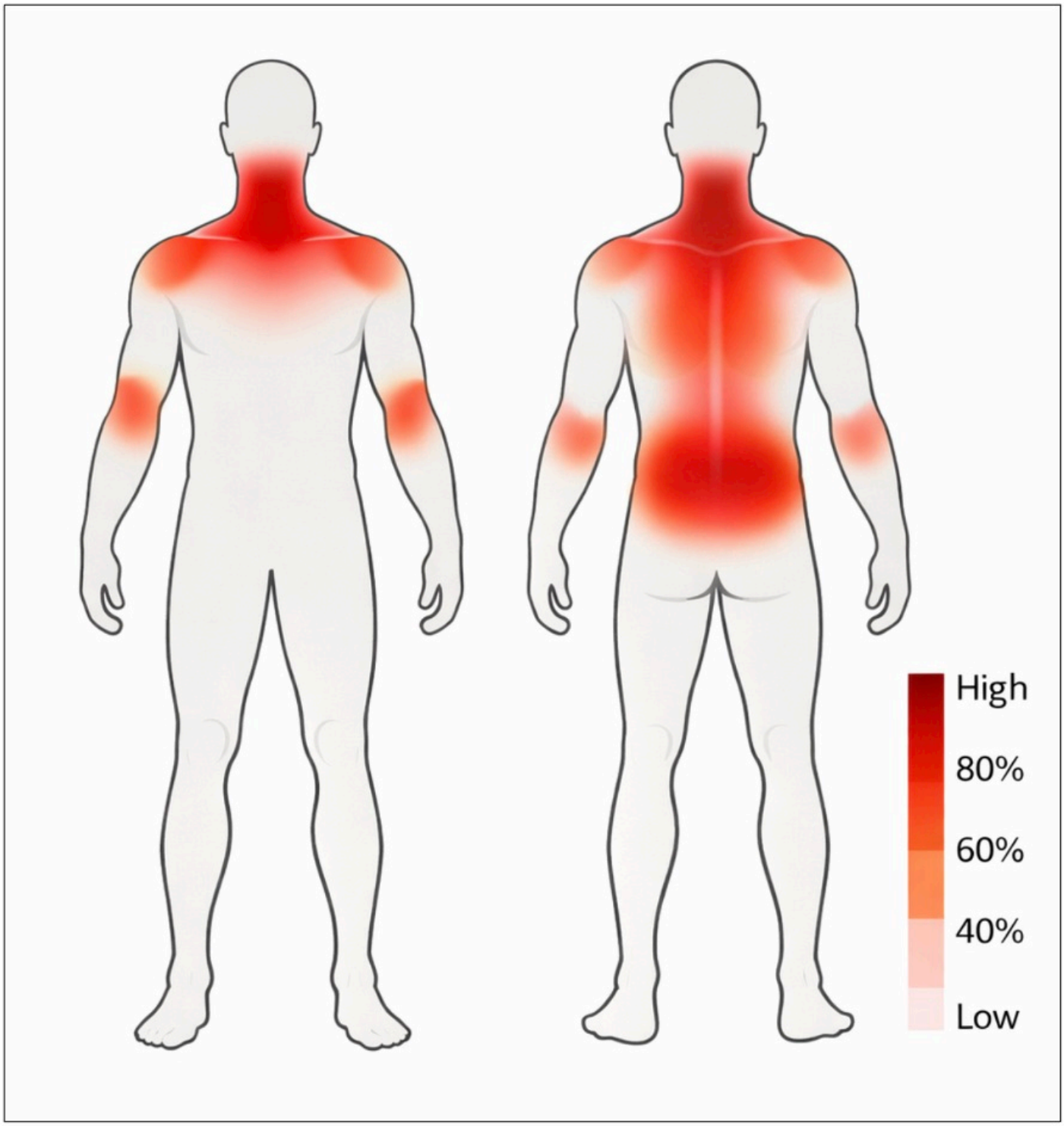


Figure 1

Anatomical distribution of self-reported musculoskeletal pain among robotic bedside assistants