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Impact of Ergonomic Interventions in Cleft Palate Surgery: A Cross-Sectional Analytical Study Assessing Surgeon Performance and Perceived Patient Outcomes

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Abstract

Cleft palate surgery requires prolonged concentration, precise visualization, sustained fine-motor control, and maintenance of operative posture, all of which may expose surgeons to ergonomic strain and musculoskeletal discomfort. This study assessed ergonomic practices, fatigue, musculoskeletal discomfort, and the perceived effects of ergonomic interventions on surgical performance and patient-related outcomes among cleft palate surgeons. This cross-sectional analytical study included 75 cleft palate surgeons from Plastic Surgery, ENT, and Pediatric Surgery departments at RMH Allied Hospitals between May 2026 and August 2026. Participants were selected using stratified random sampling. The mean age of the surgeons was 38.7 ± 7.9 years, and their mean surgical experience was 11.6 ± 6.8 years. Regular ergonomic interventions were used by 51 (68.0%) surgeons. Headlights were the most frequently used intervention (57, 76.0%), followed by Galilean loupes (43, 57.3%), operating microscopes (29, 38.7%), and prismatic ergonomic loupes (24, 32.0%). The mean fatigue score was 6.1 ± 2.0 , while musculoskeletal discomfort was reported by 48 (64.0%) surgeons. Neck discomfort was the most common complaint (36,

48.0%), followed by lower-back discomfort (29, 38.7%) and shoulder discomfort (25, 33.3%). Ergonomic factors were considered a contributor to fatigue by 46 (61.3%) surgeons. Ergonomic practices were perceived to reduce intraoperative errors by 54 (72.0%) surgeons, decrease operative time by 47 (62.7%), reduce complications by 42 (56.0%), and improve postoperative recovery by 45 (60.0%). Overall, 68 (90.7%) surgeons supported incorporating ergonomics into cleft-surgery training. These findings indicate that ergonomic challenges and musculoskeletal discomfort are common among cleft palate surgeons despite substantial use of ergonomic interventions. Structured ergonomic education, appropriate visualization equipment, improved operative positioning, and objective assessment of posture may help reduce occupational strain and support surgical performance. Because the performance and patient-related outcomes were self-reported perceptions in a cross-sectional study, they should not be interpreted as proof of causal improvement in patient outcomes.

Keywords: cleft palate surgery, surgical ergonomics, musculoskeletal discomfort, surgeon fatigue, ergonomic practices, surgical performance

1. INTRODUCTION

Cleft palate surgery is a technically demanding procedure that requires sustained attention, precise visualization, fine-motor accuracy, and prolonged maintenance of operative posture. These requirements may expose surgeons to physical strain, fatigue, and work-related musculoskeletal disorders, particularly when procedures are performed in a confined operative field or require prolonged neck and trunk flexion. Work-related musculoskeletal problems are well documented across surgical specialties and may affect occupational well-being, operative endurance, work capacity, and career longevity [1–4]. Craniofacial surgeons represent a particularly relevant group because loupe magnification, headlights, microscopes, and restricted access to the craniofacial operative field can impose substantial postural demands. In a survey of craniofacial surgeons, work-related musculoskeletal symptoms were common, with the neck, lower back, and shoulders among the most frequently affected regions [5]. More recent work in craniofacial surgery has similarly emphasized the relationship between ergonomic practices, musculoskeletal symptoms, and surgeon well-being [6].

Surgical ergonomics aims to optimize the interaction between the surgeon, patient, instruments, operating table, visualization system, lighting, and surrounding equipment so that technical performance can be maintained with less unnecessary physical loading. Objective studies in different surgical specialties show that posture, equipment configuration, visualization method, and operative approach can influence neck and back angles, muscle activity, physical workload, and subjective discomfort [7–11]. These findings are clinically relevant because ergonomic strain is not limited to transient discomfort. Prolonged or repeated non-neutral postures can contribute to occupational musculoskeletal symptoms and may eventually alter work patterns or operating responsibilities [1]. At a mechanistic level, skeletal-muscle behavior reflects interactions among tension, deformation, and viscoelastic properties; theoretical modeling of muscle deformation provides additional context for understanding why sustained mechanical loading is biologically relevant, although such models do not directly measure surgeon fatigue or surgical ergonomics [12].

Visualization equipment is especially important in cleft palate surgery because the palate is approached through a relatively confined oral cavity and the surgeon must maintain a clear view while manipulating delicate tissues. Direct cleft-surgery evidence has shown that a three-dimensional exoscope can reduce cervical flexion compared with conventional visualization approaches while maintaining favorable ratings for image quality, ergonomics, and ease of use [13]. Operating microscopes may also improve illumination and visualization during palatal cleft repair, although they can increase operative time, particularly during the learning phase [14]. Prismatic loupes provide another potential strategy. In simulated surgical tasks, prismatic loupes reduced head inclination, neck-muscle activity, and neck discomfort without a significant increase in surgical errors [15]. Subsequent operating-room research likewise found reductions in neck and shoulder muscle workload, forward head bending, and postoperative neck discomfort when prismatic loupes were compared with conventional loupes [16]. These findings support careful selection of magnification and visualization systems according to the procedure and the surgeon's working posture rather than assuming that any magnification device is inherently ergonomic.

Lighting is another important element of the operative environment. A headlight can improve visualization, but its ergonomic benefit depends on how it is positioned and how the surgeon adapts head and neck posture to direct illumination. Experimental work in rhinoplasty demonstrated that headlight angle and cervical position interact to determine illumination of the operative field, highlighting the need to optimize lighting without encouraging excessive cervical flexion [17]. More broadly, studies of surgical posture show that the use of loupes or other equipment does not automatically prevent poor posture, and ergonomic effects vary with procedure type, surgeon characteristics, equipment design, and operating position [8, 18]. Therefore, assessment of ergonomic practice in cleft palate surgery should consider the combined use of visualization devices, lighting, posture, physical comfort, fatigue, and perceived effects on performance.

Despite increasing attention to surgical ergonomics, evidence specific to cleft palate surgery remains limited. Existing studies have evaluated particular visualization technologies, while fewer studies have described how cleft palate surgeons use ergonomic interventions in routine practice or how they perceive the relationship between ergonomics, fatigue, musculoskeletal discomfort, operative efficiency, and patient-related outcomes. The present study was therefore conducted to assess ergonomic practices among cleft palate surgeons, quantify self-reported fatigue and musculoskeletal discomfort, and examine surgeons' perceptions of the effects of ergonomic practices on surgical performance and patient-related outcomes. Particular attention was given to headlights, Galilean loupes, operating microscopes, prismatic ergonomic loupes, and the perceived need to include ergonomics in cleft-surgery training.

2. METHODOLOGY

This cross-sectional analytical study was conducted among 75 cleft palate surgeons from Plastic Surgery, ENT, and Pediatric Surgery departments at RMH Allied Hospitals from May 2026 to August 2026 after approval from the Ethical Review Board of Rawalpindi Medical University and Allied Hospitals. A total of 75 cleft palate surgeons were recruited using stratified random sampling with computerized random-number generation. Surgeons who were actively performing cleft palate procedures in the participating specialties were eligible for inclusion. Surgeons with minimal experience in

cleft-related procedures and resident or trainee surgeons were excluded. Equal numbers of surgeons were selected from each specialty stratum so that the final sample included 25 participants from each of the three represented specialties.

After ethical approval and written informed consent, a list of eligible cleft palate surgeons from the relevant departments was prepared, and participants were selected randomly from each specialty stratum. Data were collected using a pre-designed questionnaire administered either manually or through Google Forms. Information regarding age, gender, surgical specialty, years of surgical experience, annual number of cleft palate surgeries, and frequency of ergonomic-equipment use was recorded. The use of specific ergonomic interventions, including Galilean loupes, operating microscopes, prismatic ergonomic loupes, headlights, and other ergonomic modifications, was assessed. Surgeons also reported perceived physical comfort, postural fatigue, visual clarity, instrument handling, communication, overall fatigue, musculoskeletal discomfort, anatomical location of discomfort, and the extent to which they attributed fatigue to ergonomic factors. Surgeon performance was evaluated through self-reported or perceived intraoperative errors and perceived effects of ergonomic practices on operative time, complications, and postoperative recovery. The fatigue result reported in this manuscript was recorded on the study's 1–10 fatigue rating scale, consistent with the scale presented in Table 3. Because the surgical performance and patient-related outcome variables were based on surgeon perception rather than independently adjudicated clinical outcomes, they were interpreted as perceived effects and not as direct evidence of causal patient benefit.

Data were entered and analyzed using SPSS version 29.0. Quantitative variables, including age, duration of surgical experience, annual cleft palate caseload, fatigue score, and physical comfort score, were summarized as mean $\pm$ standard deviation where appropriate. Categorical variables, including gender, specialty, use and frequency of ergonomic interventions, musculoskeletal discomfort, pain location, attribution of fatigue to ergonomic factors, and perceived effects on surgical outcomes, were presented as frequencies and percentages. Differences in quantitative variables between surgeons using and not using ergonomic interventions were planned for assessment with the independent-samples t-test when parametric assumptions were satisfied. Associations between categorical variables were planned for evaluation using the chi-square test, with an appropriate exact test where expected cell counts were insufficient. A two-sided p-value ≤ 0.05 was considered statistically significant. The present Results section reports the descriptive findings available in the study dataset and tables; no inferential result was introduced where a corresponding test statistic or p-value was not provided.

3. RESULTS

The surgeons had a mean age of 38.7 ± 7.9 years and a mean surgical experience of 11.6 ± 6.8 years. Of the 75 participants, 52 (69.3%) were male and 23 (30.7%) were female. Plastic Surgery, ENT, and Pediatric Surgery each contributed 25 (33.3%) participants, reflecting the stratified sampling structure. The mean annual cleft palate caseload was 28.4 ± 15.7 procedures. Thirty-one (41.3%) surgeons had less than 10 years of surgical experience, whereas 44 (58.7%) had 10 years or more. Regular use of at least one ergonomic intervention was reported by 51 (68.0%) surgeons, while 24 (32.0%) reported only occasional use or non-use. The demographic and professional characteristics of the study population are summarized in Table 1.

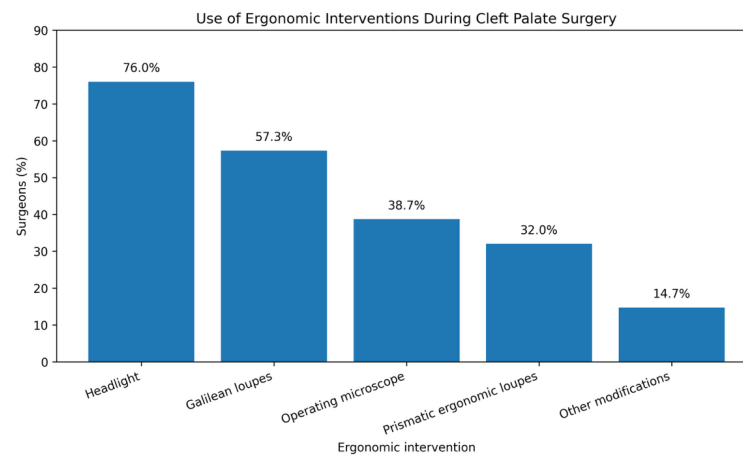
Table 1. Demographic and Professional Characteristics of Cleft Palate Surgeons ($n = 75$)

Variable	n (%) / Mean $\pm$ SD
Age (years)	38.7 ± 7.9
Male	52 (69.3)
Female	23 (30.7)
Plastic surgeons	25 (33.3)
ENT surgeons	25 (33.3)
Pediatric surgeons	25 (33.3)
Years of surgical experience	11.6 ± 6.8
Cleft palate surgeries/year	28.4 ± 15.7
<10 years of experience	31 (41.3)
≥ 10 years of experience	44 (58.7)
Regular use of any ergonomic intervention	51 (68.0)
Occasional/non-use	24 (32.0)

Headlights were the most commonly used ergonomic intervention and were reported by 57 (76.0%) surgeons. They were followed by Galilean loupes in 43 (57.3%), operating microscopes in 29 (38.7%), prismatic ergonomic loupes in 24 (32.0%), and other ergonomic modifications in 11 (14.7%). With respect to frequency of use, 32 (42.7%) surgeons reported always using ergonomic interventions, 19 (25.3%) reported using them often, 16 (21.3%) used them sometimes, and 8 (10.7%) never used them. Overall, 61 (81.3%) surgeons believed that ergonomic practices improved their surgical experience, 9 (12.0%) reported some improvement, and 5 (6.7%) reported no improvement. These patterns are presented in Table 2, while Figure 1 provides a visual representation of the use of ergonomic interventions during cleft palate surgery.

Table 2. *Use of Ergonomic Interventions During Cleft Palate Surgery (n = 75)*

Ergonomic intervention	n (%)
Headlight	57 (76.0)
Galilean loupes	43 (57.3)
Operating microscope	29 (38.7)
Prismatic ergonomic loupes	24 (32.0)
Other ergonomic modifications	11 (14.7)
Always use ergonomic interventions	32 (42.7)
Often use ergonomic interventions	19 (25.3)
Sometimes use ergonomic interventions	16 (21.3)
Never use ergonomic interventions	8 (10.7)
Believe ergonomic practices improve surgical experience	61 (81.3)
Do not believe they improve surgical experience	5 (6.7)
Somewhat improve surgical experience	9 (12.0)

**Figure 1.** *Use of Ergonomic Interventions During Cleft Palate Surgery*

The mean fatigue score was 6.1 ± 2.0 on the study's 1–10 rating scale, while the mean physical-comfort score was 3.2 ± 1.0 on the 1–5 scale. Musculoskeletal discomfort was reported by 48 (64.0%) surgeons. The neck was the most frequently affected region, reported by 36 (48.0%) participants, followed by the lower back in 29 (38.7%), shoulders in 25 (33.3%), upper back in 21 (28.0%), and wrist or hand in 17 (22.7%). Forty-six (61.3%) surgeons attributed their fatigue to ergonomic factors. The perceived ergonomic contribution to fatigue was described as minimal by 12 (16.0%) surgeons, moderate by 30 (40.0%), and significant by 28 (37.3%), whereas 5 (6.7%) reported no fatigue. The distribution of fatigue, comfort, musculoskeletal discomfort, and the perceived ergonomic contribution to fatigue is detailed in Table 3.

Table 3. *Surgeon Fatigue, Comfort, and Musculoskeletal Discomfort (n = 75)*

Variable	n (%) / Mean $\pm$ SD
Fatigue score (1–10)	6.1 ± 2.0
Overall physical comfort score (1–5)	3.2 ± 1.0
Musculoskeletal discomfort present	48 (64.0)
Neck discomfort	36 (48.0)
Lower back discomfort	29 (38.7)
Shoulder discomfort	25 (33.3)
Wrist/hand discomfort	17 (22.7)
Upper back discomfort	21 (28.0)
Fatigue attributed to ergonomic factors	46 (61.3)
Minimal ergonomic contribution to fatigue	12 (16.0)
Moderate ergonomic contribution	30 (40.0)
Significant ergonomic contribution	28 (37.3)
No fatigue reported	5 (6.7)

Ergonomic practices were perceived to reduce intraoperative errors by 54 (72.0%) surgeons; 13 (17.3%) were unsure, and 8 (10.7%) perceived no reduction. Operative time was perceived to decrease by 47 (62.7%) participants, remain unchanged by 24 (32.0%), and increase by 4 (5.3%). Similarly, 42 (56.0%) surgeons perceived a reduction in complications, while

45 (60.0%) perceived improvement in postoperative recovery. These responses represent surgeon perceptions and should not be interpreted as independently verified changes in patient outcomes. A substantial majority, 68 (90.7%), believed that ergonomics should be emphasized during cleft-surgery training, whereas 3 (4.0%) disagreed and 4 (5.3%) were unsure. The complete distribution of perceived effects on surgical performance and patient-related outcomes is presented in Table 4.

Table 4. *Perceived Effects of Ergonomic Practices on Surgical Performance and Patient Outcomes (n = 75)*

Outcome	n (%)
Ergonomic practices perceived to reduce intraoperative errors	54 (72.0)
No perceived reduction in errors	8 (10.7)
Unsure about effect on errors	13 (17.3)
Operative time perceived to decrease	47 (62.7)
No perceived effect on operative time	24 (32.0)
Operative time perceived to increase	4 (5.3)
Complications perceived to decrease	42 (56.0)
No perceived effect on complications	29 (38.7)
Complications perceived to increase	4 (5.3)
Postoperative recovery perceived to improve	45 (60.0)
No perceived effect on recovery	26 (34.7)
Recovery perceived to worsen	4 (5.3)
Ergonomics should be emphasized in cleft surgery training	68 (90.7)
No	3 (4.0)
Unsure	4 (5.3)

4. DISCUSSION

This study identified a substantial burden of musculoskeletal discomfort among cleft palate surgeons. Overall, 48 of 75 surgeons (64.0%) reported musculoskeletal discomfort, and the mean fatigue score was 6.1 ± 2.0 . The neck (48.0%), lower back (38.7%), and shoulders (33.3%) were the most frequently affected regions. These findings are closely aligned with the craniofacial-surgery literature. Shah et al. reported work-related musculoskeletal symptoms in 64.2% of surveyed craniofacial surgeons, with the neck, lower back, and shoulders among the most commonly affected anatomical regions [5]. Scarcella et al. subsequently demonstrated that musculoskeletal symptoms remain an important occupational and well-being concern among craniofacial surgeons [6]. Similar patterns have also been reported in broader plastic-surgery populations, including Canadian and Indian surgeons, in whom neck and back complaints are common and prolonged or awkward posture is frequently identified as a contributing factor [2, 4].

The observed fatigue and discomfort are biologically and ergonomically plausible in the context of cleft palate surgery. Surgeons work through a restricted oral field and may maintain static or near-static cervical and thoracic positions for prolonged periods while simultaneously performing precise hand movements. Objective ergonomic studies in other specialties have shown that non-neutral cervical-thoracic posture can be measured during surgery and that procedure type and operative approach influence the proportion of time spent in more favorable postures [8, 9, 11]. The present study did not directly measure joint angles or muscle activation and therefore cannot establish the mechanical pathway responsible for the reported symptoms. Nevertheless, the findings are consistent with a broader body of evidence linking sustained posture and surgical workload with neck, shoulder, and back symptoms [1, 7]. Theoretical work on skeletal-muscle deformation also emphasizes that muscle behavior depends on tension, deformation, and viscoelastic response, providing a general mechanical context for why sustained loading deserves attention, although such modeling should not be treated as direct evidence of clinical fatigue in surgeons [12].

Ergonomic equipment was widely used in the present study. Headlights were reported by 76.0% of surgeons, Galilean loupes by 57.3%, operating microscopes by 38.7%, and prismatic ergonomic loupes by 32.0%. Despite this substantial uptake, musculoskeletal discomfort remained common. This finding reinforces an important point: ownership or use of an ergonomic device does not necessarily guarantee an ergonomic working posture. Studies among ophthalmic, spine, and other surgeons show that musculoskeletal symptoms may persist despite loupe use and that ergonomic burden is influenced by operating duration, equipment characteristics, surgeon posture, case volume, and procedural demands [7, 18]. Therefore, ergonomic interventions should be evaluated as part of an integrated operating-room system rather than as isolated devices.

The type of visualization technology may nevertheless influence posture and physical workload. In cleft surgery, Lee et al. found that a 3D exoscope reduced cervical flexion compared with conventional visualization methods while receiving favorable ergonomic and image-quality ratings [13]. In palatal cleft repair, Demiröz et al. reported improved visualization with an operating microscope, although the microscope group experienced longer operative times, particularly during the learning process [14]. Evidence for prismatic loupes is also relevant. Fan et al. showed in simulated surgical tasks that

prismatic loupes reduced head inclination, neck-muscle activity, and neck discomfort without a significant difference in surgical errors [15]. Yang et al. subsequently evaluated prismatic loupes during real operations and found reductions in upper-trapezius and neck-extensor activity, forward head bending, and postoperative neck discomfort compared with conventional loupes [16]. Taken together, these studies indicate that visualization systems can alter physical workload, but the magnitude of benefit depends on design, fitting, task demands, and adaptation.

Lighting should be considered in the same integrated manner. The present study found headlights to be the most commonly used ergonomic intervention. Experimental work in rhinoplasty has shown that headlight angle and cervical flexion jointly influence illumination of the operative field [17]. Thus, a headlight can support visualization while still encouraging undesirable posture if the light source, surgeon position, table height, or operative target are poorly aligned. This distinction is particularly important in cleft palate repair, where the surgeon may compensate for limited visualization by increasing cervical flexion. Future cleft-specific ergonomic studies should therefore record not only whether a headlight or loupe is used but also how it is fitted, positioned, and integrated with patient and table position.

Surgeons in this study perceived ergonomic practices as beneficial to performance: 72.0% perceived fewer intraoperative errors, 62.7% perceived shorter operative time, 56.0% perceived fewer complications, and 60.0% perceived improved postoperative recovery. These findings should be interpreted cautiously. The study measured perceptions rather than independently verified operative errors, duration data, complications, or patient-recovery outcomes. Consequently, the results demonstrate strong surgeon belief in the value of ergonomics but do not establish that ergonomic interventions caused better patient outcomes. This distinction is consistent with intervention studies showing that ergonomic technologies can improve posture, workload, comfort, or fatigue while effects on objective surgical performance may be smaller, variable, or dependent on the intervention and learning period [15, 16, 19]. Future research should pair ergonomic exposure measures with objective surgical metrics, including operative duration, error rates, complications, postoperative outcomes, and validated workload instruments.

A particularly important finding was that 68 (90.7%) surgeons believed ergonomics should be emphasized during cleft-surgery training. This strong support is consistent with evidence showing limited formal ergonomic education among surgeons. LaMonica et al. reported that most surveyed surgeons had not received prior ergonomic training, despite a substantial burden of musculoskeletal symptoms [1]. Formal ergonomic instruction is also uncommon in rhinoplasty practice, even though interest in ergonomic assessment is high [20]. These observations support incorporating ergonomic principles early in surgical education, before maladaptive postural habits become established. Training should include operating-table height, patient positioning, neutral cervical-thoracic posture, selection and fitting of loupes, appropriate use of microscopes and exoscopes, headlight alignment, microbreaks where feasible, and recognition of early musculoskeletal symptoms.

The educational component should also be practical rather than purely didactic. Evidence from practical-readiness research outside surgery indicates that training is more meaningful when confidence is connected to observable task performance, continued transfer, and structured feedback rather than to knowledge exposure alone [21]. Although that work was conducted in laboratory education rather than surgical education and should not be interpreted as clinical evidence, the training principle is relevant: ergonomic competence should be demonstrated during real or simulated operative tasks. Surgical trainees could therefore receive posture feedback during simulation, practice equipment adjustment, and document ergonomic self-assessment during supervised procedures. Objective sensor-based approaches have already been used to quantify posture and provide biofeedback in surgical environments [9, 11].

The study has several limitations. First, its cross-sectional design prevents causal inference, and the relatively small sample of 75 surgeons limits precision and generalizability. Second, the available results are predominantly descriptive, while the protocol specified analytical comparisons; inferential estimates should be reported in future analyses where complete group-level data are available. Third, ergonomic practices, fatigue, discomfort, intraoperative errors, operative time, complications, and postoperative recovery were based on self-report or surgeon perception and are therefore susceptible to recall, response, and social-desirability bias. Fourth, no objective posture measurement, electromyography, wearable-sensor assessment, or direct observation of ergonomic exposure was performed. Fifth, the study did not independently verify patient outcomes or quantify whether ergonomic-device use preceded, followed, or changed musculoskeletal symptoms. Finally, the reported fatigue score was based on the study's 1–10 rating scale; future work should consider a clearly specified validated workload or fatigue instrument where appropriate.

Despite these limitations, the study provides clinically useful descriptive information from cleft palate surgeons and identifies several priorities for future research. Prospective multicenter studies could combine validated musculoskeletal questionnaires, objective posture monitoring, device-specific exposure data, operative duration, surgical-error measures, complication data, and patient-recovery outcomes. Such studies would help determine which interventions reduce biomechanical burden, whether benefits persist over time, and whether improved surgeon ergonomics translates into measurable changes in surgical efficiency or patient care.

5. CONCLUSION

Ergonomic challenges and musculoskeletal discomfort were common among the cleft palate surgeons included in this study despite frequent use of headlights, loupes, operating microscopes, and other ergonomic interventions. Neck, lower-back, and shoulder discomfort were particularly common, and many surgeons attributed at least part of their fatigue to ergonomic factors. Most participants perceived ergonomic practices as beneficial to operative comfort and performance, and an overwhelming majority supported incorporating ergonomics into cleft-surgery training. Because the study was cross-sectional and the performance and patient-related outcomes were based on surgeon perception, the findings should not be interpreted as proof that ergonomic interventions directly reduce complications or improve postoperative recovery. Nevertheless, the results support structured ergonomic education, careful selection and fitting of visualization equipment, appropriate lighting and operative positioning, and future objective assessment of posture and workload. Prospective studies that combine ergonomic exposure measurements with independently verified surgical and patient outcomes are needed to determine which interventions provide durable benefits for surgeons and whether those benefits translate into measurable improvements in clinical performance.

AUTHOR CONTRIBUTIONS

All authors contributed equally to the conception, development, preparation, and revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTERESTS

The authors declare that they have no conflicts of interest.

DATA AVAILABILITY

No new dataset was generated or analyzed.

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