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General surgeons' occupational musculoskeletal injuries: A systematic review

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ABSTRACT

Introduction: Surgeons are expected to work long hours in operating theatres. A high prevalence of work-related musculoskeletal (WRMSK) injuries and pain in healthcare professions exists. We aimed to study WRMSK pain and injuries in general surgeons and study their risk in different surgical techniques comprising open, laparoscopic and robotic-assisted surgery.

Methods: A systematic search was performed in compliance with The PRISMA checklist. Search was performed in PubMed and Cochrane library databases for 6 years to 2024. The search terms used were “disability and surgeon”, “occupational injuries and surgeon”, and “musculoskeletal pain and surgeons”, in addition to MESH terms in PubMed database. Risk of bias was calculated among studies.

Results: The search revealed 3648 citations from which a final list of 24 citations were included after application of inclusion and exclusion criteria. The citations comprised over 1900 surgeons including consultants and surgical trainees from different subspecialties. Incorporated citations consisted of 21 cross-sectional 3 observational studies. Most common pain sites, risks and preventative measure for MSK injuries were revealed.

Conclusion: There is high prevalence of WRMSK pain among general surgeons. Surgeons were primarily affected at physical body parts ranging from the neck, shoulders, upper back and lower back to upper extremity. Robotic-assisted surgery led to lower post-operative discomfort and decreased demanding muscle activity in upper extremities but enhanced static neck position resulting in subjective back stiffness compared with laparoscopic surgery.

Introduction

Surgeons are expected to work long hours in operating theatres. A high prevalence of work-related musculoskeletal (WRMSK) injuries and pain in healthcare professions exists [1–3]. An injury or illness is referred by the Occupational Safety and Health Administration to be work-related if an event or exposure in the work environment either caused or contributed to the resulting condition or significantly intensified a pre-existing condition. Lack of ergonomic training or poor ergonomic habits during operating often lead to musculoskeletal (MSK) injuries which can affect the surgeon's wellbeing and career longevity, e.g., in forms of burnout, chronic disability and early retirement [4].

Surgical modality impacts the incidence of WRMSK pain which is estimated to range from 66% to 94% among those who perform open surgery [5]. A previous study proved that open surgery affected most surgeon's lower back, neck and upper back [6]. Also, laparoscopic

surgery impacted the same body parts in a similar order but robotic surgery differed and had a significantly lower effect on neck, upper back and lower back.

We aimed to study MSK pain and injuries in general surgery and its sub-specialties such as breast, endocrine, lower gastrointestinal, upper gastrointestinal, hepatobiliary and bariatric surgery. We also aimed to include WRMSK injuries in different surgical techniques comprising open (OS), laparoscopic surgery (LS) and robotic-assisted surgery (RAS).

Method

Data search

A systematic search was performed in compliance with The PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) checklist [7].

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Search was performed in PubMed and Cochrane library databases for 6 years to January 2024. The search terms used were “*disability and surgeon*”, “*occupational injuries and surgeon*”, and “*musculoskeletal pain and surgeon*”, in addition to MESH terms in PubMed database.

Inclusion and exclusion criteria

We included citations about WRMSK injuries with focus on those endured by general surgeons. We excluded reviews, case reports, conference abstracts, semi-structured interviews, letters to editors and studies that studied WRMSK pain in other specialities. We excluded citations containing very minimal number of general surgeons (e.g. 1–2 participants) and those in medical students. Articles in non-English language were also excluded.

A detailed literature search was performed, by inspecting titles, abstracts, and reading the full text of the relevant papers. The revealed citations were reviewed against the inclusion and exclusion criteria. The inclusion and exclusion criteria were clearly pre-determined, and citations were read in full text for further assessment of quality and to analyse the risk of bias across studies.

The citations were quality rated, and evidence graded. Quality was determined to cover average response rate (33%), internal reliability, external validity, MSK pain site and advice on management as well as general limitation or bias. These criteria were rated in the quality assessment as follows: If >85% of these criteria were completed the quality was considered high; moderate quality was assumed if 65–84% were completed, low quality was given if 45–64 % of the criteria were finished and insufficient quality comprised less than 44% of the criteria.

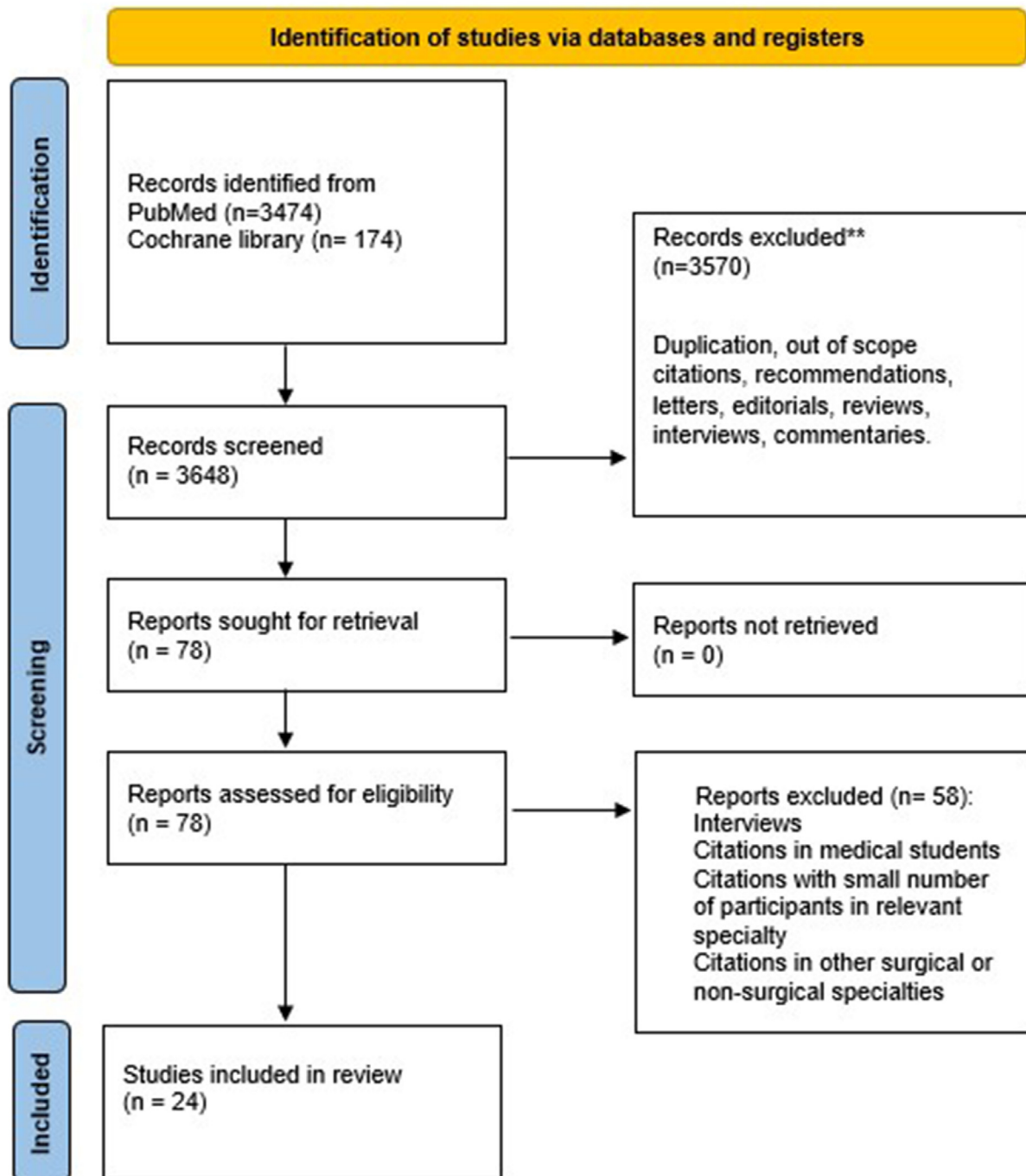


Fig. 1. Study flow diagram.

Analysis

Data were extracted and analysed using Excel 2016 (Microsoft Corporation, Redmond, California, USA). Information collected for each citation included citations description (title, authors, year of publication, Journal), aims, findings, surgical speciality, open, laparoscopic or robotic surgery, symptoms site, risk of MSK pain and recommendations.

Results

The search revealed 3648 citations from which a final list of 24 citations were included after applying the inclusion and exclusion criteria (Fig. 1) [8–31].

The included citations consisted of 21 cross-sectional and 3 observational studies. The risk of bias in each study was analysed and

Study	Risk of bias domains					Overall
	D1	D2	D3	D4	D5	
Dianat et al.	-	+	+	+	+	+
Gutierrez-Diez et al.	-	+	+	-	+	-
Alnefaie et al.	-	+	+	+	+	+
AlSabah et al.	-	+	+	-	X	X
Dalager et al.	-	+	+	+	-	-
Wells et al.	-	+	+	-	+	-
Dwyer et al.	-	+	+	+	+	+
Grant et al.	-	+	+	-	+	-
Yang et al. A	X	-	-	+	+	X
Alhusuny et al.	-	+	+	-	+	-
Athanasiadis et al.	-	+	+	-	+	-
Ratâ et al.	-	+	+	-	+	-
Yang et al. B	-	+	+	-	+	-
Aldaheri et al.	-	+	+	+	+	-
Jensen et al.	-	+	+	+	+	+
Michael et al.	-	+	+	-	+	-
Monfared et al.	-	+	+	+	+	+
Owada et al.	-	-	+	+	+	-
Alshareef et al.	-	+	-	+	+	-
Bishop et al.	-	+	+	+	+	+
Dixon et al.	-	+	+	+	+	+
Durden et al.	-	+	+	-	+	-
Liu et al.	-	+	+	-	+	-
Shah et al.	-	+	+	-	+	-

Domains:
D1: Bias arising from the randomization process.
D2: Bias due to deviations from intended intervention.
D3: Bias due to missing outcome data.
D4: Bias in measurement of the outcome.
D5: Bias in selection of the reported result.

Judgement
X High
- Some concerns
+ Low

Fig. 2. Included studies rated against the risk of bias tool.

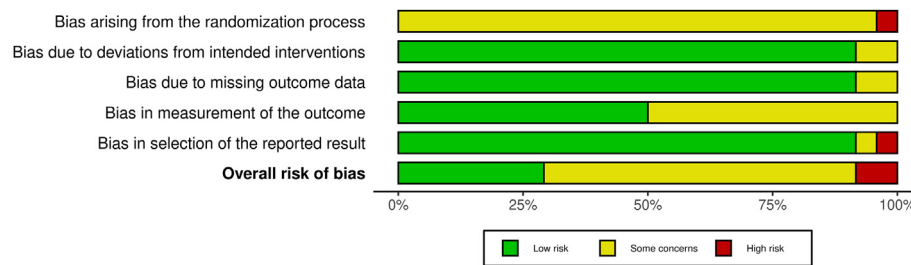


Fig. 3. Risk of bias summary assessment among studies.

summarised in Figs. 2 and 3. Three of the 24 studies were of high methodological quality [24,25,31] and seven were of moderate methodological quality [10,19,26–30]. It was revealed on evidence grade 1 based on 2 high quality citations [24,31] that surgeon's MSK pain was associated with their unnatural postures for longer time during surgery. Tabular summary of the aims and findings of the included citations about WRMSK is presented in Table 1.

More than 1900 surgeons including consultants and surgical trainees from different subspecialties such as bariatric, colorectal, hepatobiliary, oesophagogastric and endocrine surgery were included. The sample size, gender, age and symptom sites are described in Table 2. Risk factors and preventive factors for MSK are given in Table 3.

When looking in detail where surgeons had their most painful body sites, we can observe that the surgeons were primarily affected at physical body parts ranging from neck pain [10,17,22,26–31], shoulders [10,17,18,25,27,30], back pain, upper back and lower back [10,18,26–31], to upper extremity [18] (Fig. 4). A great risk factor for developing MSK injuries consists of having been subject to a previous MSK injury [23,26]. Some recommendations were provided how to decrease the risks for MSK injuries, and some studies put forward strategies to cope with MSK pain by means of exercise, development of muscle strength and the use of stretching before and after surgery. In addition, improving surgeon's posture during operation and rearranging theatre ergonomically may be used as coping strategies to tolerate the discomfort [8,16,18,20] (Table 3).

Furthermore, MSK pain by modality was observed and recorded [11,19,20]. One study [20] found that the prevalence of neck and lower back pain was significantly higher after OS than after LS. Another one [11] revealed in his study that over the last 12 months 71% reported significant pain from OS but LS was indicated as 1% more painful (72%); furthermore, 48% found RAS painful and 51% felt that endoscopy was painful [19]. It was found that right deltoid and trapezius excessive muscle activity was higher in LS compared to RAS. RAS led to lower post-operative discomfort and decreased demanded muscle activity in upper extremities but increased static neck positioning resulting in subjective back stiffness compared with LS (Table 2).

Surgeons did not suffer solely from physical discomfort but also from mental apprehension in forms of fatigue [25,26,31], fears of loss of career longevity due to pain, feelings of burnout, co-worker's scolding, irritation and situational stress [11,25] (Table 3).

General surgeons' high prevalence of WRMSK pain and discomfort did not hold them back from daily performance of what was expected from them. Female surgeons were more likely to be symptomatic. Only 19% of them had learned about ergonomic adjustments during their training. More than 2/3 of respondents were unaware of ergonomic solutions e.g. bad posture and there were those who did not consider accepting any suitable preventive measures at all. A good recommendation comprised the suggestion that a systematic ergonomic examination of workplace conditions and regular counselling sessions should take place to encourage surgeons to use their backs more properly with correct posture.

Discussion

Occupational damages in healthcare workers comprise a high prevalence of WRMSK injuries which challenges the healthcare systems [32]. Surgeons long working hours in operating theatre put them at high risk of MSK injuries. This has been proven in different surgical subspecialties including cardiothoracic, orthopaedic and plastic surgery [4,33,34]. We conducted this systematic review on MSK injuries in general surgeons to study the most common affected body sites and the risk-factors. We also aimed to include WRMSK injuries from different surgical techniques including OS, LS and RAS in general surgery.

Minimally invasive surgery has become the routine technique for many surgical procedures over the past two times. However, the harmful effect on surgeons repeatedly performing LS for long hours must be recognised. In LS, surgeons often hold their neck in a stationary posture while simultaneously holding the shoulder muscles in an abducted, immobile position during lengthy cases [35,36]. Surgeons performing minimally invasive surgery are likely to experience three to five times more neck and shoulder pain than surgeons performing OS [37]. It has also been shown that a higher case load predicted increased symptoms for OS and LS, but not for RAS [6]. Robotic surgery was less likely than OS or LS to lead to neck, back, hip, knee, ankle, foot, and shoulder pain and was less likely compared to LS to cause elbow and wrist pain.

Surgeons' MSK pain sites were analysed with both subjective and objective measures across a variety of specialities [27]. After performing surgical cases, surgeons felt increased pain most frequently in the neck, lower back, upper back, and right shoulder, in order of magnitude. It has previously been shown that almost half of the surgeons experienced multisite MSK pain along with a high pain intensity reporting four or more painful body sites [28]. More than a fifth of the surgeons used analgesics several times a week, and 40% of the surgeons had sometimes or often sleeping problems. Thirty-seven surgeons had MSK pain in one body site. The neck and lower back were the most painful body sites. Lower back was the most painful body site in OS, the shoulders were the most painful body sites in LS, and in RAS the neck was the most painful body site. LS was surgeon's most painful surgical modality to perform, followed by OS.

Surgical procedures demand different work postures [27], OS operators had the most challenging postures of the neck, trunk, and right upper arm. The duration of surgery generated greatly fatigue. It was revealed about surgeon's MSK pain that more than half of the surgeons had taken action to reduce their pain. Initiatives related to ergonomics, for example, changing table height, placement of screens. Further, they performed physical exercise and strength training or running. Also, by seizing microbreaks during surgery, or by reducing number of operations or by taking analgesics before surgery [28] the surgeon can decrease the pain. Ergonomic lectures and workshops ought to be examined by improved knowledge and awareness of one's own habits while operating, along with the education's perceived benefit for the surgeon. The emerging adoption of film review facilitates surgical training and practicing, and highlights the surgeon's improved ergonomic awareness [4].

Table 1
Tabular presentation of aims and findings of the included citations.

Author (year)	Aim of citation	Findings
Dianat et al. (2018)	To evaluate the effect of physical, psycho-social and individual factors on the presence of musculoskeletal symptoms among surgeons	Seventy seven percent experienced MSK symptoms at some time during the twelve months prior to the study. General surgeons experienced lower rates of symptoms compared to cardiothoracic and obstetric/gynecologic surgeons
Gutierrez-Diez et al. (2018)	To investigate the influence of musculoskeletal disorders (MSKD) on surgeons performing Minimally invasive surgery (MIS) using the standardized valid Nordic questionnaire	The prevalence of MSKDs is higher in MIS surgeons. Eight suffered from episodes with temporary working disability due to injuries related to previous MSKD. No significant difference between genders was found
Alnefaie et al. (2019)	To determine the prevalence of work related MSK manifestations among surgeons in a tertiary care hospital and to identify the possible associated risk factors.	Most respondents (80%) suffered from MSK manifestations that were related to performing surgeries. Back and neck areas represented the most affected body parts. A higher percentage of those with musculoskeletal manifestations practiced for 5-10 years
AlSabah et al. (2019)	To investigate the prevalence of musculoskeletal (MSK) injuries in bariatric surgeons around the world	In total 66% of surgeons experienced some level of discomfort/pain due to surgical activity. The back was most affected during OS, while shoulders and back were equally affected in those performing LS. The neck was most affected during RAS
Dalager et al. (2019)	To study MSK pain among surgeons working in the fields of pelvic surgery.	High prevalence of multisite musculoskeletal pain and a high pain intensity exist amongst pelvic surgeons. Almost half of the surgeons experiencing multisite musculoskeletal pain reported four or more painful body sites.
Wells et al. (2019)	To explore work-related pain and discomfort among members of the European Association for Endoscopic Surgery (EAES) who were practicing surgeons.	Over half of practicing surgeons reported that their worst pain score was 3.8 (SD 2.7) or higher out of a 10-point pain scale in the past 7 working days
Grant et al. (2020)	To estimate prevalence and identify risk factors for developing work-related musculoskeletal disorder (WRMSKD) affecting neck, shoulder and upper back pain in surgeons	Surgeons reported shoulder, neck or upper back pain in a 7-day period, 31% had pain preventing normal work in a 12-month period. The prevalence of WRMSKDs amongst surgeons is high, females and younger surgeons reporting increased pain rates
Dwyer et al. (2020)	To use validated ergonomic tools to assess the posture of RAS surgeons to examine posture deficiencies.	The positions of surgeons that deviated from an ideal central postural line were recorded. Rapid Entire Body Assessment (REBA) and the Rapid Upper Limb Assessment (RULA) were employed to assess posture using a still image at 15 min. The average RULA and REBA scores meet the requirements of medium risk with the recommendation that action is needed to improve ergonomics.
Yang et al. (2020)	To assess the workload of surgeons and procedure types to identify ergonomic risk factors using both subjective measures and objective measures.	Surgeons reported increased pain in the neck, upper, and lower back both during and after operations. High-stress intraoperative postures were also revealed. Surgeons experienced increased pain after performing surgery most frequently in the neck, lower back, upper back, and right shoulder. Open surgery had the most demanding postures of the neck, trunk, and right upper arm.
Alhusuny et al. (2021)	To Determine the prevalence and severity of neck/ shoulder problems and visual symptoms independently and combined.	Neck/shoulder problems and visual symptoms were reported by 31.0% and 29.0%, respectively, 15.5% reported both problems. The prevalence and severity of neck/shoulder problems and visual symptoms were significantly associated
Athanasiadis et al. (2021)	To assess the ergonomic risk of surgical trainees as compared with ergonomic risk of experienced surgeons	Both trainees and consultants spent a similarly high percentage of each case in static (>60%) and demanding positions (>5%). Trainees were more tired and had a longer static posture than consultants. The surgeons had suffered from WRMSK complaints at least in one body part during the last year. Most surgeons reported pain in four body parts.
Ratâ et al. (2021)	To examine the prevalence of work-related musculoskeletal (WRMSK) complaint and its potential risk factors among Romanian surgeons.	Procedural time impacted on fatigue, body-part pain, and subjective (NASA-TLX) workload. Surgeons spent an alarmingly high percentage of time during surgery in high-risk musculoskeletal postures, especially affecting the neck
Yang et al. (2021)	To assess surgeon's intraoperative workload, fatigue, and musculoskeletal pain during open and laparoscopic surgery	Thirty-eight percent of surgeons (n = 79) had back pain. The highest prevalence was revealed among general surgeons
Aldaheri et al. (2022)	To assess the prevalence and the characteristics and identify associated risk factors among surgeons in Saudi Arabia	MSK symptoms were present in 90% of respondents, most notably in forms of pain (91%) and stiffness (81%). The most common locations were neck (87%) and shoulders (55%)
Jensen et al. (2022)	To study work-related injury and Musculoskeletal (MSK) symptoms among endocrine surgeons	The prevalence of WRMSK disorders was 12% before beginning the practice of LS compared to 78% after 15–20 years of practice. The incidence of WRMSK among MIS surgeons is underestimated
Michael et al. (2022)	To assess the prevalence of WRMSK disorders among MIS surgeons in Israeli Society of Endoscopic Surgery MIS is a risk for WRMSK disorders	Robotic assisted surgeries led to less postoperative discomfort and muscle strain in both upper extremities, chiefly on surgeon's dominant side, but increased static neck positioning with subjective back stiffness compared with LS
Monfared et al. (2022)	To compare ergonomic risks among surgeons and surgical trainees performing LS and RAS procedures across specialities	Of the surgeons 56.6% reported low pain, and 43.4% reported high pain in the last month. The age and years of work correlated with the degree of pain. The number of surgeries, rate of LS and operation time did not correlate with pain group
Owada et al. (2022)	To find out the prevalence and risk factors for surgeons' work-related musculoskeletal (WRMSK) disorders in Japan	Surgeons had a high level of neck and back pain. The prevalence of back, neck, and shoulder pain among the surgeons was 68.2%, 56.9%, and 46.2%, respectively, while the overall prevalence of MSK pain was 87.2%
Alshareef et al. (2023)	To determine the prevalence of back and neck pain among Saudi surgeons of all specialities	

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Table 1 (continued)

Author (year)	Aim of citation	Findings
Bishop et al. (2023)	To evaluate the prevalence and impact of MSK-P among surgical trainees	Trainees from general surgery (the largest programme with 48% of respondents). Most trainees (75%) sought no treatment. No trainees missed work despite pain
Dixon et al. (2023)	To assess the current rates of pain and discomfort across a cohort of laparoscopic surgeons from multiple countries	Ninety percent reported pain due to performing laparoscopic surgery. Longer average operative duration and a greater number of years in practice were both associated with a significantly higher prevalence of pain
Durden et al. (2023)	To study the prevalence of MSK in surgeons at a UK hospital. Different operating techniques and their impact on MSK injuries on work and home were in focus of interest	In total 86.5% of the surgeons reported MSK discomfort over the last year, with 92% detailing issues over the last 5 years
Liu et al. (2023)	To evaluate muscle pain, fatigue, verbal scolding, and task load for surgeons and camera-holder assistants	In total 81% of operating surgeons and 78% of camera-holder assistants reported muscle pain/discomfort during the procedure. 55.2% of camera-holder assistants reported verbal scolding from the operating surgeons, primarily attributed to lapses in laparoscope movement coordination
Shah et al. (2024)	To quantify treatment utilization for all-cause musculoskeletal (MSK) symptoms in surgeons and trainees at a single institution as self-reported on a survey.	Altogether 87.3% (48/55) of respondents reported musculoskeletal pain in the past 7 d, with most reporting moderate pain (40.0%). Prevalence of pain was similar between consultants and trainees (85.3% and 90.5%)

Table 2

Tabular presentation of number of subjects, surgical technique and symptoms' sites.

Author (year)	No of General Surgeons (GS)	Gender	Age (years)	OS	LS	RAS	Symptoms' site
Dianat et al. (2018)	73	Male 48 Female 25	45				Knees (48.7%), neck (45.8%), low back (42.3%) and shoulders (40.1%).
Gutierrez-Diez et al. (2018)	27/129	Male 79 Female 50	Male 44 Female 39		27		Neck, upper back, lower back, lower limbs, right shoulder and right-hand. Male surgeons have the highest pain prevalence in the lower back. In Female surgeons, the highest prevalence is in the neck
Alnefaie et al. (2019)	33/121	Male 74 Female 47	24-30		67		Back (71.1%) and neck (59.8%) represented the most affected body parts
AlSabah et al. (2019)	113 Bariatric surgeons	Male 107 Female 6	45	74	77	10	Back in open surgery, back and shoulders in LS Neck pain in robotic surgery
Dalager et al. (2019)	130/373	Female 109	57				The neck (63%) and lower back (60%) were the most prevalent painful body sites
Wells et al. (2019)	556	Male 467 Female 89	Range: 20-71	244	248	166	Neck, shoulders, upper back, lower back, fingers or thumb
Grant et al. (2020)	252/329	Male 240 Female 88	48				Neck n = 194 Shoulder n = 180 Upper back n = 125 Neck, shoulder or upper back n = 245. Females > more than males pain in neck, shoulder and upper back in last 12 months
Dwyer et al. (2020)	4	Male 2 Female 2				4	Body posture deficiencies in head, shoulders, mid-spine, hips and knees were revealed
Yang et al. (2020)	Total 53 surgeons	Male 34 Female 19					Neck, upper and lower back and shoulder
Alhusuny et al. (2021)	56 GS and colorectal surgeons/290	Male 152 Female 138	46	56			Neck/shoulder pain was most frequent, following visual problems and next came both. Surgeons reporting severe visual symptoms were six times more likely to relate to severe neck/shoulder pain
Athanasiadis et al. (2021)	20	Male 11 Female 9	43 consultants 31 trainees				The main physical areas affected included back stiffness, left hand/wrist pain, neck stiffness, and right arm/shoulder stiffness
Ratā et al. (2021)	6/95	Male 56 Female 39	37 Range: 25-64				WRMSK complaints most often in 4 body parts: Lower back, neck, shoulder, upper back, knee, wrist-hand, elbow, hip and ankle-foot

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Table 2 (continued)

Author (year)	No of General Surgeons (GS)	Gender	Age (years)	OS	LS	RAS	Symptoms' site
Yang et al. (2021)	24	Male 13 Female 11	Male 43 Female 42				Neck, upper back and lower back. Surgeons spend a significant percentage of time during surgery in high-risk postures, especially for the neck
Aldaheeri et al. (2022)	52/208	Male 145 Female 63	36				Cervical, Cervical/Lumbar, Cervical/Lumbar/Sacral, Cervical/Thoracic/Sacral/Lumbar, Lumbar, Sacral, Sacral/Thoracic, lumbar
Jensen et al. (2022)	220 Endocrine surgeons	Male 147 Female 66	48				Neck 174, Shoulder 110, Chest 3, Low back 84, Limb 65, Other 18
Michael et al. (2022)	83						Back pain, neck and upper extremity/shoulder pain, tennis elbow and carpal tunnel syndrome
Monfared et al. (2022)	20	Majority were men			48	29	Right finger numbness and right shoulder stiffness and surgeon irritability after laparoscopy and back stiffness after robotic surgery
Owada et al. (2022)	106/174 GS		42	90	60		For OS, pain was most common in the neck, followed by the lower back and shoulder. For LS, the prevalence was highest for the shoulder, followed by the lower back and neck. The prevalence of neck and lower back pain was higher after OS than after LS
Alshareef et al. (2023)	83 GS, 1 hepatobiliary, 1 colorectal/195	Male 129 Female 66	Range: 31–35				Back, neck, and shoulder pain
Bishop et al. (2023)	24/53	Male 28 Female 23. No answer (n = 2)	30 Range: 26–41				Neck, lower back pain, often in a month or daily disturbing work and life outside work
Dixon et al. (2023)	115 GS including colorectal, hepatobiliary/259						Common pain in back, shoulder, neck, wrist/hand. Less often in knee, elbow, foot/ankle and hip
Durden et al. (2023)	40						18/37 had shoulder pain, 16/37 lower back and 14/37 had neck problems. Only 5/37 did not report any MSK within the last year
Liu et al. (2023)	94		37 surgeons 26 assistants				Pain in shoulders, upper limbs (arms, wrists, palms, and lower back). 69 surgeons reported persistent muscle pain after surgery
Shah et al. (2024)	55	Male 34 Female 21	47.5 consultants 31. trainees				The most affected body parts included the neck, upper back, and lower back

OS – more experience in open surgery.

LS – more experience in laparoscopic surgery.

RAS – robotic-assisted surgery.

Table 3

Riskfactors and preventative measures for MSK injuries.

Author (year)	Riskfactors for MSK injuries	Preventive measures for MSK injuries
Dianat et al (2018)	Long hours spent on surgeries each week, number of hours working in standing position per day, surgery duration, work-family conflict, the number of years worked as a surgeon and gender (being female)	The prevalence of neck, shoulder and low back pain decreased with more time (>2 h) spent on sport/physical activities each week
Gutierrez-Diez et al. (2018)	The most vulnerable group consists of experienced surgeons and there is a potential risk that symptoms will increase in the future	Muscle strength is a protective factor against WRMSKD
Alnefaie et al.(2019)	Long operating duration, lifting body parts manually and shortage of staff	Medical and non-medical therapies such as massage which was the most commonly used followed by ointment/cream use then hot packs.
AlSabah et al. (2019)	Those who exercised >3 h/week had shoulder and wrist pain in both OS and LS. Supine positioning of patients caused more discomfort in surgeon's wrists, while the French position caused more discomfort in the back region	Exercise less than 3 h per week
Dalager et al.(2019)	Being female and physical work demands	Initiatives taken: ergonomics (57%), e.g. changing table height, placement of screens, physical exercise training (30%) e.g. strength training or running, performing microbreaks during surgery (6%)
Wells et al. (2019)		The use of RAS induces the least amount of pain in surgeon

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Table 3 (continued)

Author (year)	Riskfactors for MSK injuries	Preventive measures for MSK injuries
Grant et al. (2020)	Physical discomfort was a fear-provoking risk factor for inability to perform surgical procedures in the future. These surgeons' higher callousness toward people is also a risk factor for work dissatisfaction Predictors for increased WRMSKD prevalence were: female gender, younger age and fewer years of working	Ergonomics education must be incorporated in formal teaching and research must validate an ergonomic and physical conditioning program to prevent WRMSKD
Dwyer et al. (2020)	Robotic surgery lacks in proper ergonomic positioning for the surgeon. Medium risk for MSK complications exists already from average RULA and REBA scores.	It is imperative to improve the risk robotic surgery poses to surgeons. Improved ergonomics prevent MSK and may prolong the careers of surgeons.
Yang et al. (2020)	The work posture of surgeons performing open operations was significantly more demanding for neck, trunk, and right upper extremity, as measured objectively by the Intraoperative Musculoskeletal Discomfort system	No specific preventative measures. Defining intraoperative ergonomic risk factors is of paramount importance to protect the well-being of the surgical workforce.
Alhusuny et al. (2021)	Riskfactors in workplace were temperature, asymmetrical weight bearing and forward head movement, female gender and wearing vision correction glasses. Neck/shoulder problems and visual symptoms followed	By improving ergonomics, the risk for MSK is decreased
Athanasiadis et al. (2021)	Trainees' who have to hold their trunk static a longer time are at risk for pain	Interventions to reduce ergonomic risk in the operating room are needed
Ratã et al. (2021)	Surgeons had high risk of severe pain in upper back, lower back and knees. Their WRMSK pain affected both professional and personal life	No clear preventative measures. Studies must identify risk factors and ergonomic and educational strategies to reduce the prevalence and impact of WRMSK injuries
Yang et al. (2021)	Intraoperative work postures using wearable sensors showed a high MSK risk for neck and lower back based on their overall posture	Intraoperative postural risk presents a hazard to surgeons; interventions must aim at protecting MSK health to improve surgeons' career longevity
Aldaheiri et al. (2022)	Longer work experience had a higher percentage of back-pain. Independent risk factors of back pain among studied surgeons were older mean age, and a higher mean BMI	Researchers advocate an ergonomic examination of workplace conditions and regular counselling sessions to encourage surgeons to use their backs more properly with correction of posture
Jensen et al. (2022)	Female surgeons were more likely to be symptomatic. Only 19% had learned about ergonomic adjustments during training	The most common ergonomic regulations were stretching, the use of microbreaks and headlight/loupe adjustments
Michael et al. (2022)	More than 2/3 of responders were unaware of ergonomic solutions for bad posture and there were also those who did not consider accepting any suitable preventive measures	Surgeons should adhere to ergonomic recommendations for positioning of monitors, table height, posture, foot pedal placement and use of laparoscopy
Monfared et al. (2022)	The recognized ergonomic differences between RAS and LS can raise surgeon awareness of the intraoperative posture	There is a need to develop targeted physical and occupational interventions to decrease surgeon WRMSKD and increase surgeon longevity
Owada et al. (2022)	Chronic WRMSK pain affected those ≥ 30 years old and the pain increased with age	Stretching (pre and post-surgery) was used for pain, followed by postural adjustment and physiotherapy
Alshareef et al. (2023)	Male surgeons, fatigue during long days, and the cause of fatigue was LS procedures	No clear preventative measure. More studies should be conducted to identify and prevent MSK riskfactors to improve the outcomes and prevent further complications
Bishop et al. (2023)	MSK pain begins during training, occurs regularly, and affects function. Neck pain restricted ability to work and perform activities outside the work	No preventative measures mentioned. Interventions are needed to reduce the impact of chronic pain on patient care, surgeon wellness, and career longevity
Dixon et al. (2023)	Surgeons with pre-existing injury benefit from avoiding LS. Poor knowledge of ergonomics is a contributory factor in inadequate MSK outcomes	Normalizing MSK pain and injury in surgeons is the beginning of strategies to prevent them. The benefit of integrating more ergonomic education into surgical training is advocated
Durden et al. (2023)	Lack of awareness of the impending epidemic of occupational health injuries endanger our healthcare	No clear preventative measures. International data and analysis is needed to ensure we are preventing disability amongst colleagues
Liu et al. (2023)	The physical and mental health harms experienced by camera-holder assistants during LS need special attention. Prolonged operation time may have a greater bearing on mental health	Improving working environment of camera-holder assistants to minimize physical and mental health distress improves the working interest, reducing job burnout, and delaying professional life
Shah et al. (2024)	76.4% required some form of treatment for MSK and related disorders: 63.6% had taken over the counter pain medication	No preventative measures mentioned. 10.9% got prescription pain medication and 25.5% got physical therapy

Namely, lack of proper ergonomic training or poor ergonomic habits during surgery often lead to MSK injuries which are likely to have serious prospective bearings on the surgeon's life, economy and career longevity, resulting in burnout, chronic disability and ending in an early retirement [38].

Yet, across all surgical modalities and platforms, the performing of an operation may put the surgeon at risk for developing chronic MSK injuries. In such a physically demanding profession, injury prevention and anticipation are critical. This can also be accomplished through a combination of optimizing operating room ergonomics and health maintenance through improved training regimens. Generally, surgeons lack awareness and proper training as regards beneficial operative posture, ergonomics, and risk moderation through practice variations, adjustments of the working environment, and prevention strategies [39]. Nevertheless, numerous ergonomic interventions exist such as intraoperative break programmes [40], wearable exoskeletons for disabled surgeons [37,41] along with operating theatre reconfiguration [42,43]

and other things that are already there to help preventing development of WRMSK injuries in surgeons.

Limitations

A limitation of this study was to solely include general surgeons to learn about their WRMSK injuries in OS, LS and RAS due to the restricted number of studies that defined general surgeons among other participants. However, we excluded those in other subspecialties and conducted risk of bias analysis in the included studies. Twenty four citations were counted in with a good number of participants from general surgery subspecialties performing operation by means of different surgical modalities. Implications of surgical subspecialties can be a focus of future research. Yet, the preventative measures in each of general surgeon's applied surgical technique have to be in focus of interest in upcoming research to create unique interventions to minimize the operator's short-term or long-term harmful and painful aftermath.



Fig. 4. General surgeons' work-related musculoskeletal injuries common body sites (OpenArt AI used to create this figure).

Conclusion

There is a high prevalence of WRMSK pain among general surgeons. A great risk factor for developing MSK pain consists of having been subject to a previous MSK injury. Surgeons were primarily affected at physical body parts ranging from the neck, shoulders, upper and lower back to upper extremity. Improving surgeon's posture during operation may be used as a coping strategy to tolerate the discomfort. RAS led to lower post-operative discomfort and decreased demanding muscle activity in upper extremities but increased static neck positioning resulting in subjective back stiffness compared with LS. Exercise, development of muscle strength and stretching before and after surgery were recommended to decrease the risks for MSK injuries.

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Declaration of competing interest

The authors declare no conflict of interests.

List of abbreviations

WRMSK	work-related musculoskeletal
MSKD	musculoskeletal disorder
MSK	musculoskeletal
OS	open surgery
LS	laparoscopic surgery
RAS	robotic-assisted surgery
MIS	minimally invasive surgery

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