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Abstract

Background

Musculoskeletal disorders (MSDs) are an occupational hazard amongst surgeons, causing detrimental effects in up to 20% of surgeons in their lifetime. However, there is a paucity of data examining solutions for the problem. There is also a lack of research comparing MSDs in surgeons who perform open surgery compared with those who perform newer methods of surgery such as laparoscopic and robotic surgery.

Aims

We aim to explore existing literature about the various risk factors and the consequences of MSDs. We believe that by raising awareness of such risk factors to medical students from early on in their medical careers, they can develop an appreciation of the potential long-term impacts and take an early approach to prevention. We discuss preventative strategies in the categories of individual, occupational, institutional, and intra-operative techniques.

Materials and Methods

Ovid Medline, Cochrane Library, and PubMed databases were used to identify articles. Studies reporting on work-related MSDs in surgeons were included. Articles relevant to medical fields with a high level of surgical involvement, such as gynaecology, were also included. This information was used to construct a narrative review of the literature (see Appendix 1 for full methodology). Within each database search, only a few articles relevant to this review were generated. Therefore, the citations were also screened to find additional articles that fit within the scope of this review.

Results

Multiple factors were found to contribute to the development of MSDs, including individual and occupational factors. MSDs have resulted in a high percentage of surgeons performing fewer surgeries or taking more time off work. Similar risk factors applied to laparoscopic and robotic surgery. Few studies examined strategies to combat MSDs, but techniques such as intraoperative exercise and ergonomic training have shown to be promising.

Conclusion

There is a need for ongoing research into strategies to prevent MSDs in surgeons. Currently there are no evidence-based guidelines for management of work-related MSDs. Medical students should be aware that this occupational hazard has deleterious effects on the body and should be encouraged to employ some of the currently available strategies to prevent MSDs. The authors of this review advocate for ergonomics education to be integrated into surgical training programs via collaboration between ergonomists and surgical program directors.

Main Learning Points

1. MSDs in surgeons are under-researched but are still an important occupational hazard that can be potentially debilitating.
2. There are no guidelines to manage MSDs – current best strategies involve having a well-balanced lifestyle, seeking help early, and being ergonomically aware of mechanisms of injury.
3. Greater awareness of ergonomics among surgeons could possibly reduce the incidence of MSDs among high risk groups.

Introduction

Work performed by healthcare professionals, especially surgeons, carries an inherent risk for physical wellbeing. One of the most common examples are musculoskeletal disorders (MSDs), which is an umbrella term that includes pain and injuries to various muscles and bones of the body [1]. Examples of MSDs include carpal tunnel syndrome and rotator cuff tendonitis. MSDs commonly arise from factors such as the overuse of certain muscle groups, poor posture, and sustained positions that strain the body. If not addressed early, MSDs can reduce work productivity and result in prolonged disability [1]. Doctors are at high risk of developing work-related MSDs, due to risk factors such as long hours of standing, extended working hours, and lack of periods of rest [2]. This is even more so in surgeons, who tend to experience greater severity and incidences of MSDs due to the physical nature of their work [3]. Yet, less attention has been given to work-related MSDs than other occupational hazards such as burnouts [4].

In Australasia, the incidence of MSDs among surgeons is about 27% [1]. In the United States, the rates are even higher at around 40% [1]. This can impact on the surgeons' daily performances, as well as cause long-term disabilities. The only strategies available currently revolve around recuperating or seeking physiotherapy help, and are not preventative.

In this review, we will focus on the specific hazards that surgeons face, the consequences of the hazards, and some of the novel solutions created to manage and prevent these injuries. Ultimately, we hope to facilitate awareness of such injuries amongst medical students and aspiring surgeons and discuss current strategies to combat MSDs.

Methods

Literature review of articles from MEDLINE (Ovid), PubMed (National Library of Medicine), and Cochrane Library was performed. Included articles reported information on the prevalence, consequences, prevention, and proposed solutions of work-related MSDs. MeSH terms used were "musculoskeletal disorders" and "surgeons" and combined with the prefix 'AND'. UpToDate articles regarding the mechanism for musculoskeletal injury were consulted as they described the pathophysiology of MSDs comprehensively. There were no language restrictions in any of the searches (refer to Appendix 1 for complete methodology).

Studies on the prevalence of work-related MSDs amongst surgeons

There is currently a paucity of quality data about the prevalence of MSDs in the healthcare profession. A systematic review by Epstein *et al.* included studies on the prevalence of MSDs among doctors. Sixteen studies qualified under the inclusion criteria, and most of them were cross-sectional or survey studies with considerable heterogeneity [1]. From the systematic review, the overall lifetime prevalence of degenerative musculoskeletal disease amongst surgeons was reported to be 19% [1], with the highest prevalence of MSDs reported at 87%, by gynaecological oncologists [5]. The same systematic review also showed that different specialties have higher incidences of certain types of MSDs (Table 1) [5-11], though in general, the neck, back, upper limb, and shoulders are the most common locations for MSDs.

A study by Davis *et al.* reports that less than 40% of recordable injuries were reported to their respective institutions [11]. One possible reason could be lack of knowledge on accessing institutional support, however studies identifying these reasons are lacking [11]. Surgeons frequently experience physical discomfort while performing surgery [5-11]; over 85% [5] report this, however poor ergonomic working conditions within the operating theatre are usually tolerated, and likely under-reported.

Specific risk factors

The development of MSDs is multifactorial and influenced by individual, occupational, and situational factors (Figure 1).

Figure 1 – The multifactorial development of MSDs in surgeons

During non-neutral postural positions, frequently used during surgery, extended periods of isometric action put pressure on the cartilage. Pro-inflammatory cytokines eventually erode the articular cartilage, causing degenerative osteoarthritis. Simultaneous reactive growth of bony spurs [osteophytes] either impinge nerve roots or affect the spinal canal, both of which can lead to chronic pain [12]. Inflammation and repeated stress can also cause disc herniation to occur and cause radiculopathy, with similar negative effects on surrounding muscles and tendons. Repeated and extended periods of action and stress can tire out muscles and put excess tensile loading on the tendons, which in turn causes more impingement and pain [13].

Individual factors, such as age, comorbidities, and past trauma directly affect the integrity of the joint and tendon anatomy. Aging tendons, for instance, are more prone to microtears and calcifications, which can predispose the surgeon to a higher likelihood of MSDs when coupled with repetitive overuse [13].

Occupational factors, such as posture and positioning during surgery and work schedule, affect the loading of the joint or tendon. During surgery, surgeons often adopt awkward positions for extended periods, placing unnatural pressures on joints, tendons, and muscles. Work scheduling and work periods without break affect the duration of action on the affected structure, which then cause progressive degeneration [14]. Poor sitting postures in review clinics are also contributory to MSDs.

Finally, workplace factors such as work culture affect surgeons' tolerance and response to pain [1]. Short leaves for work-related MSDs, confusion over what constitutes a reportable injury, and acceptance of pain as part of the surgeon's role all delay help-seeking behaviours and reporting of symptoms [11].

Consequences of work-related MSDs on surgeons

The consequences of MSDs can be divided into short-term and long-term categories (Figure 2). The short-term impacts influence the surgeons' daily performance, while long-term consequences may influence surgeons' well-being and futures based on the degree of debilitation.

Figure 2 – The impact of MSDs on surgeons can be significant both in the short and long-term

The presence of pain and discomfort from a musculoskeletal disorder can impact on surgeons' posture, mobility, level of concentration, and physical stamina [15]. Most surgeons do not usually operate every day [15], which allows rest time for injuries; for some, symptoms persist even during the recovery days. 41% of surgeons report that pain affected their relations with other people, while 51% reported that it affected their sleep [15]. In the United

States, 22% of work-related MSD injuries resulted in missed work and 35% of work-related MSD injuries resulted in surgeons performing fewer surgeries [11]. Approximately 5% of respondents took at least two weeks off work to recuperate from injuries [11], with economic and logistical implications [11]. In the UK, 23% of work-related MSD injuries sustained by otolaryngologists resulted in taking time off work [16].

In more severe cases, MSDs can cause surgeons to restrict the number of surgeries performed per day, undergo surgery themselves, or even retire prematurely. There have been no studies done on the long-term implications of MSD on aging surgeons, however, Epstein *et al.* approximated that 12% of surgeons required leave of absence, practice restriction, or even early retirement due to MSDs [1].

Minimally invasive surgery (MIS), whilst offering several benefits to the patient, including smaller incisions, less postoperative pain and infection risk, and quicker postoperative recovery, has the potential to cause greater strain on the surgeon [10]. Compared to conventional surgery, MIS is associated with an increased risk of disc herniation [17] and a tendency to require longer periods of static posture, especially of the neck [18], which predisposes to MSDs. Due to the unique motions of laparoscopic instruments, laparoscopic surgeons can develop a unique MSD known as the laparoscopist's thumb [19]. Conversely, open surgery provides a greater range of motion [18]. There have been no systematic reviews comparing MSDs between MIS and open surgery so far. It is clear, however, that an awareness of the increased musculoskeletal strain, particularly associated with poor ergonomics, is imperative for the surgeon to employ measures to mitigate these risks.

General strategies for the prevention and treatment of MSDs

At present, there are no evidence-based recommendations for management of work-related MSDs. Based on current practices, the following framework for the prevention and management of MSDs was formulated (Figure 3).

Figure 3 – There are institutional, occupational, and individual strategies in addressing MSDs

Individual level

Personal health reduces the number of comorbidities and negative factors that can predispose to MSDs. Workers in all occupations are encouraged to stay healthy by adhering to a balanced diet of fruits and vegetables with less intake of free sugars and saturated fats, and a moderate aerobic exercise regime of 30 minutes on most days [20]. This is because healthy eating and exercise is associated with a better quality of life and lower risk of musculoskeletal pain, especially in the long-term [21]. Therefore, surgeons are advised and encouraged to keep active and eat healthy to meet the demands of the job. Unfortunately, due to the poorer work-life balance and long hours, only about a third of surgeons engage in regular exercise and this can predispose them to MSDs [22].

Traditionally, surgeons would turn to therapy and/or pharmacological analgesia after surgery to numb musculoskeletal pain. One study briefly looked at alternative therapies employed by surgeons who had sustained an MSD. Of those who had MSDs, 44% sought assistance from a

physiotherapist or an occupational therapist, 23% managed on simple analgesia alone and 13% tried alternative therapy, such as acupuncture and Ayurvedic medicine [23]. There is minimal data on the effectiveness of such strategies. On the whole, the effectiveness of these therapies depended on the individual surgeon's MSD and the skill of the therapist.

General occupational level

Occupationally, surgeons would benefit from basic awareness regarding proper posturing and exercises, as well as additional support when performing surgery. In a survey of surgeons on methods to reduce the incidence of work-related stress injuries [11], responses included "early education as to what position can lead to injury", "a formal curriculum for residents in training about how to reduce the likelihood of injury", and "lifting assistance during manual handling of patients" [11]. Ongoing research is looking into strategies to improve surgeon posture and surgical ergonomics [24], which are two of the key risk factors associated with the development of MSDs. One randomised clinical crossover trial examining a group of surgeons who participated in an interventional program based on ergonomic principles reported significant reduction in lower back pain and analgesic consumption compared to pre-trial [24].

The Alexander technique (AT), is a method of psychophysical re-education of the body, teaching users to have greater awareness of postural strains in their body. It has been previously used for musculoskeletal conditions [25] and this was tried as a strategy to improve posture during surgery [26]. In a study, seven subjects were taught the Alexander technique by a professional AT coach face-to-face over two group sessions, six individual lessons and exercises in their own time, and then assessed twice for laparoscopic skills before and after the intervention. All reported significant improvements to their posture and ergonomics, which would then decrease the risk of MSD [26].

For surgeons already with MSD, Kinesio Tape, a type of kinetic tape which is normally used for injuries in athletes, was used to help such surgeons achieve better functional performances during surgery [22]. In this study, the tapes were applied to the trapezius or the sacrospinal muscles for relief of shoulder and back pain over several days. Kinesio Tape showed a significant improvement in scores of both the Neck Disability Index (3.84 to 2.52) and the Oswestry Low Back Disability Index (4.38 to 2.77) in surgeons [22] and significantly improved the cervical range of motion from 0.35 to 0.59 [22].

Intraoperative strategies

When faced with pain in the middle of an operation, surgeons use varying techniques to reduce symptoms while operating; 25% of surgeons slowed down the pace of the surgery, 63% changed positions, and 38% adjusted their equipment to suit their needs, be it to allow for a different posture or to rest [15]. These strategies however are often limited by constraints of the sterile field and the instruments, and consequently physical symptoms persist.

In prolonged surgeries, surgeons are prone to fatigue, decreased strength, and technical accuracy. Some studies have investigated the use of microbreaks during surgery in order to reduce MSDs [15,27,28]. One crossover experimental study demonstrated that micropauses of less than 20 seconds every 20 minutes was shown to significantly improve strength and reduced the number of technical errors by sevenfold during evaluation. Surgeons were given 20 seconds of time for stretching and rest every 20 minutes for long surgeries, and physical discomfort was evaluated using a visual analogy scale, with follow-up fatigue and accuracy testing by holding a weight and using a pair of Metzenbaum scissors to cut out a star-shaped track after the surgery respectively. No impairment of surgical performance was reported [27].

Besides using micropauses, there is also some evidence that specific stretching exercises during surgery have the potential to reduce MSDs and enhance performance. Two multi-centre cohort studies were done on the use of intraoperative microbreaks with stretching exercises to combat physical fatigue and discomfort during surgery [15,28]. Surgeons were asked to perform standardised exercises that worked the neck, shoulders, hands, and back that lasted 90 seconds at appropriate 20 to 40-minute intervals throughout the surgery. Both studies showed significant reduction in pain symptoms as well as improvement in physical performance [15,28]. There was marked improvement of pain in the shoulders [15,28] as well as improvement of pain in the back and neck [28]. Already, there has been development of an exercise set that addresses the increased strain on select muscle groups during surgery [29].

Future research could be done to explore the long-term consequences of microbreaks and standardised exercises during surgery.

Organisation level

Institutional reporting allows surgeons to access institutional support and receive adequate compensation for their injuries [30]. However, due to fears of medicolegal matters, institutions may instead recommend measures on reporting surgeons that are unsatisfactory, such as forced leaves. In a study done in Tennessee, United States, up to 30% of surgeons surveyed did not know how to report occupational injuries, which was defined as “any wound or damage to the body resulting from an event in the work environment”, to their institution [11]. Medical institutions should be reminded of their legal obligation to protect their employees’ health and thus should promote general education about the reporting process, enabling surgeons to seek medical help earlier. The reporting process should also be done in an anonymous manner so as to avoid reputational harm for either the surgeon or the medical institution.

Ergonomics: A novel solution?

While doing a literature search of solutions to control MSDs among surgeons, the field of ergonomics was at the forefront of the list. Ergonomics is described as the science of improving the efficiency of human performance within their working environment [31,32].

A number of studies have been done on analysing surgical work from an ergonomic point of view. Ergonomic assessment of the surgical theatre has shown that surgeons work in conditions similar to or even harsher than those of industrial workers [33-37]. Furthermore, surgeons have shown to be severely lacking in ergonomic awareness and knowledge. Only 25.4% of surgeons have undergone any type of ergonomics education, which in part explains the acceptance of poor ergonomics in their working environment [1,33,34]. With such a great need for workplace reforms in surgery, ergonomics can play a vital part in the surgical world, by understanding the interaction between surgeon’s posture, surgical procedure, and work environment, in order to devise ways to reduce the risk of injury and the burden of MSDs [1].

However, implementation of an ergonomic intervention is not without its difficulties. It appears that a key challenge has been the standardisation and measurement of ergonomics in surgery. A computerised observational tool, ErgoPART, was developed to quantify postural demands of surgery [38]. It is a software designed to record, track, and measure the frequencies and duration of surgeons’ postures during surgery in real time [38]. As surgeons maintain positions for long periods of time during surgery, ErgoPART was able to code these positions. Using broad categories to classify different body postures, ErgoPART successfully managed to help quantify the frequency and duration of non-neutral body postures [38]. In addition, ErgoPART has also been used to look at pain outcomes based on the postural

differences between sitting and standing and the postural differences between primary surgeons and assistant surgeons during vaginal surgery [39,40]. Collection of more data is necessary to make recommendations to reducing work-related MSDs. Future research could develop new quantitative measurements of musculoskeletal stress. Combined with some basic ergonomics training, this should adequately equip surgeons with techniques to reduce incidence of MSDs in the long-term.

Specific to MIS, ergonomic assessment revealed that laparoscopic surgery was even more taxing on the surgeon [41]. One possible reason for this is that laparoscopic instruments come in standard sizes and lengths which may not fit the hands of all surgeons. Given that MIS is quickly becoming the mainstay mode of surgery in view of the patient benefits, it is pertinent to optimize ergonomics for the MIS work environment.

Implications of the article

Further research is warranted to examine solutions to reduce MSDs among surgeons in a systematic approach, either in terms of ergonomic changes to the work environment, or in terms of education so that surgeons can avoid such injuries pre-emptively.

This article remains very relevant for all medical students. Aspiring surgeons should be aware of such occupational hazards and pay attention to their own physical health, as well as that of their peers and superiors. Since there is a shortage of high-quality studies on the topic of MSDs in surgeons, research-inclined medical students can endeavour to conduct studies in this area or contribute to such studies if already ongoing. Furthermore, while searching the literature, we found evidence that the problems of MSDs are also prevalent in physicians, albeit at a lower rate. This means that all medical students should be aware that their future occupation will also predispose them to MSDs and develop adaptive habits of self-care.

Limitations of the article

The authors of this narrative review acknowledge that, unfortunately, most of the data on this subject is observational, and there are no systematic reviews on strategies for preventing MSDs among surgeons. However, it is precisely the shortage of longitudinal and interventional studies that motivates the writing of this review article, so that awareness on this issue is increased and can hopefully spur more interest in this area of self-care for doctors. While searching the literature, results for ergonomic interventions of microsurgery, laparoscopic, and robotic surgery were generated. While MSDs for newer forms of surgery are beyond the scope of this article, it would be an interesting area to research in the future.

Conclusion

Surgeons are at high risk of developing MSDs because of personal, occupational, and workplace-based factors, with deleterious effects for both the patient and surgeon. While current data is predominantly observational, it is well demonstrated that MSDs are an increasing issue amongst the surgical profession. Yet, there are no formal recommendations on how surgeons can avoid or manage MSDs. At present, a well-balanced lifestyle, with improved clinician education regarding ergonomic principles on reducing musculoskeletal strain during surgery are the only general advice for preventing MSDs. In the future, there will likely be more evidence to support incorporating ergonomics into surgical training programs. Through this article, medical students should have a greater awareness of MSDs and learn to practise greater self-care.

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Authors Contribution

XS performed the literature review, drafted the first version of the article and made revisions as per supervisor and editor suggestions, AA proofread the article and approved final submission, SN performed literature review, edited the article and approved final submission, PN proposed the outline of the article, created diagrams, oversaw the literature review and edited the manuscript.

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Appendix 1

Table 1: List of studies

Inclusion criteria

Studies that examined work-related musculoskeletal disorders in doctor population samples of a surgical background were used. Specialties that had a high level of surgical involvement, such as gynaecology, were also included. All studies from the 1990s through to June 2019 were included. Due to the lack of studies on both the prevalence of MSDs and solutions against MSDs, there was no language restriction on any of the searches. Only 83 articles were generated, of which only 20 were compatible with the aims of this article. Thus, the citations of these studies were also screened to search for articles missed by the preliminary search.

Exclusion criteria

Studies involving non-surgical specialty health practitioners, interventionalists, as well as other allied health professions, such as nursing, were excluded. Studies that were case studies and case series were excluded. Articles that were not studies, such as newspaper articles and lecture materials, were excluded.

Search terms used

The following search terms were used: musculoskeletal disorders, surgeons, work-related, occupational, prevalence, incidence, strategies, solutions, ergonomics. These search terms were combined for various parts of this review article using the Boolean operator 'AND'.

Title	Author	Study aims	Methods	Outcomes of study	Study findings
Prevalence of Work-Related Musculoskeletal Disorders Among Surgeons and Interventionalists [1]	Epstein S, Sparer E, Tran B, <i>et al.</i>	“To estimate the prevalence of work-related MSDs among at-risk physicians and to evaluate the scope of preventive efforts.” [1]	“Systematic search in MEDLINE (Ovid), Embase (Elsevier), Web of Science, PubMed, and 2 clinical trial registries, for studies reporting on the prevalence and prevention of work-related MSDs among at-risk physicians published until December 2016.” [1]	21 articles were included in this systematic review, all of which had considerable heterogeneity.	Primary finding of this study showed that musculoskeletal disorders amongst surgeons have a 19% overall lifetime prevalence which cannot be ignored. Other interesting findings include a gross lack of awareness of ergonomics in surgery which can potentially mitigate musculoskeletal disorders.
Prevalence of work related musculoskeletal disorders among physicians, surgeons and dentists: A comparative study [3]	Rambabu T, Suneetha K.	To evaluate and compare work-related MSDs across three groups: physicians, surgeons and dentists	Self-reporting questionnaires on MSDs were distributed, including information on the location of MSD symptoms in the past 12 months and the pain experienced, to a small sample size of 300.	Musculoskeletal pain was most prevalent among dentists at 61%, followed by surgeons at 37%, and physicians at 20%.	There is a higher prevalence of MSDs experienced by dentists than both surgeons and physicians.
Musculoskeletal disorders among vaginal surgeons [5]	Kim-Fine S, Weaver A, Woolley SM, Gebhart J.	“To estimate the prevalence of MSDs in vaginal surgeons and identify work-related characteristics in order to guide further research” [5]	De novo surveys were distributed to members of the International Urogynecological Association and American Urogynecological Society. Exclusion criteria included inability to read English, no computer access, invalid or unavailable e-mail address, and missing >50% of responses.	18% of members responded. Among respondents, 86.7 % reported ever having work-related MSDs.	A large proportion of vaginal surgeon respondents reported work-related MSDs, majority of these involving the neck and back. These surgeons were also more likely to be female, younger, and be in surgical teaching.
Work-Related Musculoskeletal	Epstein S, Tran B, Capone	To synthesize the available	Literature search conducted using Medline, Embase, Web of Science, and	16 articles were included in this systematic review. The evidence was of poor	High prevalence of MSDs amongst plastic surgeons are worrying and need to

Disorders among Plastic Surgeons: A Systematic Review [6]	A, Ruan Q, Lee B, Singhal D.	literature regarding prevalence of MSDs, and potential solutions to treat MSDs amongst plastic surgeons	PubMed until 2016 for all articles reporting on prevalence of work-related musculoskeletal injuries or ergonomic challenges amongst plastic surgeons	quality, but points at a high prevalence of career-related musculoskeletal injury amongst plastic surgeons.	be researched further. Half of the articles looked at altering ergonomics of surgery.
Musculoskeletal Disorders Among Spine Surgeons [7]	Auerbach J, Weidner Z, Milby A, Diab M, Lonner B.	To assess whether spine surgeons are at an increased risk of MSDs as compared to the general population	Authors modified an official Physical Discomfort Survey and surveyed members of the Scoliosis Research Society via mail and email.	62% of members responded. Mean age was 54 years old. 62% of respondents complained of neck pain, 49% complained of shoulder pain.	The authors' hypothesis was correct. Heavier caseload was correlated with higher rates of MSDs, especially in the cervical region.
Hand Problems Among Endourologists [8]	Healy K, Pak R, Cleary R, Colon-Herdman A, Bagley D.	To assess prevalence of hand problems among endourologists and generate possible causes	Computer survey given to the two different groups: members of the Endourological Society and psychiatrists in academic and community settings. Parameters queried included symptoms of hand pain, neuropathy, and/or discomfort.	20.3% of endourologists and 12.8% of psychiatrists responded, giving a total sample size of 196. Hand and wrist problems were reported by 39 (32%) endourologists compared with 14 (19%) psychiatrists.	Hand and wrist problems are prevalent among endourologists. Interestingly, surgeons who preferred a different method of surgery (counterintuitive ureteroscope deflection) were more likely to have problems.
Is shoulder impingement syndrome a problem in otolaryngologists? [9]	Mal R, Costello C.	To find out the incidence of shoulder disease in otolaryngologists compared to a control group of endocrinologists.	A brief questionnaire survey was posted to a list of members in the British Association of Otolaryngologists. Endocrinologists were used as the control group and were given the same questionnaire. Questionnaire was brief and asked for impingement syndrome without grading of symptoms.	There was a 65.1% response rate overall. 24.0% of the otolaryngologists had suffered from impingement syndrome compared with 10.9% of the endocrinologists. For those without impingement syndrome, 19.7% of otolaryngologists compared to 7.3% of endocrinologists gave history of injury or	Otolaryngologists are more affected by shoulder impingement than endocrinologists, suggesting an association between profession and injury.

				overuse.	
Patients Benefit While Surgeons Suffer: An Impending Epidemic [10]	Park A, Lee G, Seagull F, Meenaghan N, Dexter D.	“To investigate the association of demographics, ergonomics, and environment and equipment with physical symptoms reported by laparoscopic surgeons.” [10]	An online survey was sent to members of the Society of American Gastrointestinal and Endoscopic Surgeons and results were analysed using chi-square and logistic regression.	There was a response rate of 14.4%. 86.9% of respondents reported physical symptoms or discomfort. High case volume was most associated with symptoms. 58.7% reported being slightly or not aware of surgical ergonomics and its recommendations.	The high prevalence of MSDs amongst laparoscopic surgeons is very serious and needs further research beyond survey methodologies. Future guidelines on surgical ergonomics should be widely taught to surgeons.
Musculoskeletal occupational injury among surgeons: effects for patients, providers, and institutions [11]	Davis W, Fletcher S, Guillamondegui O.	To assess the likelihood of work-related musculoskeletal injury in a surgeon’s career and subsequent effects on their patients, providers, and institutions.	Authors used pre-existing surveys that assessed occupational injury and emailed to members of the Tennessee chapter of the American College of Surgeons. Descriptive statistics were used to analyse survey data and qualitative analysis was performed on open response questions.	33% of members responded. 40% of surgeons sustained ≥ 1 injuries in the workplace. 50% of injured surgeons received medical care for their most recent injuries yet 20% of these injuries were reported to their institution. 53% of injured surgeons reported that pain from their injury had a minimal or moderate effect on their performance in the operating room.	Surgeons have moderate-to-high risk for sustaining MSDs, but there appears to be a low rate of institutional reporting which must be addressed. Open responses highlighted a need for some ergonomic-based guidelines to reduce MSDs.
Work-related physical, psychosocial and individual factors associated with musculoskeletal symptoms among surgeons:	Dianat I, Bazazan A, Souraki Azad M, Salimi S.	To analyse the effects of each physical, psychosocial, and individual factor on the presence of MSDs among surgeons in	All surgeons from 3 major Iranian cities who have at least 1 year of working experience were invited to participate, giving a sample size of 500. A pre-existing survey, the standardised Nordic Musculoskeletal Questionnaire was utilised and translated into Persian language.	62.4% of surveyors responded. The following factors were associated with MSDs: Time spent on surgeries each week, number of hours working in standing position per day, moderate to high levels of work, family conflict, duration of each surgery, number of years worked as a	Improved working conditions can improve quality of life and enhance patient care overall. This study also highlights the correlation between psychosocial stressors such as family conflict, and the presence of MSDs.

Implications for ergonomic interventions [14]		Iran.	Details included demographics, a body map of musculoskeletal injuries, work-family conflict scale and details about surgery work. Data was analysed using Odds Ratio.	surgeon (>10 years), and surgical specialty, particularly cardiothoracic and obstetric and gynaecologic surgeries.	
The impact of intraoperative microbreaks with exercises on surgeons: A multi-center cohort study [15]	Hallbeck M, Lowndes B, Bingener J, Abdelrahman A, Yu D, Bartley A et al.	Does the introducing of intraoperative microbreaks with exercises during long surgeries reduce fatigue in surgeons?	Preliminary questionnaire that covered body part discomfort and after-effects was completed before intervention. The intervention involved standardized 2-minute guided microbreak exercises performed intraoperatively within the sterile field at 20–40 min intervals throughout each case over a surgical day. Other days where microbreaks were not performed were the control group. At the end of all surgical days another questionnaire was filled out to cover current self-reported physical pain. Sample size was small at 56.	80% of the surgeons self-reported that they had ongoing pain at the start of the day, with 41% reporting that the pain interfered with interpersonal relationships and 51% reporting that the pain interfered with sleep. After the intervention, 34% self-reported improvement in physical pain scores, and only 12% reported a decrement, while 57% reported physical performance improvement with none reporting a decrement in physical performance.	Microbreaks improved self-reported physical performance and mental focus during surgery, yet did not significantly increase surgery duration.
An overview of occupational hazards amongst UK Otolaryngologists [16]	Vijendren A, Yung M.	To investigate the prevalence of various OH amongst ENT doctors in the UK.	Survey was created combining two validated questionnaires for general health, and also gathered demographics and work data. With the assistance of ENT-UK, the survey was sent out to its members. A literature search was also conducted to search for articles within English literature.	24% of members responded, giving sample size of 323. 70.6 % had reported a form of OH throughout their career. The literature search also revealed 16 articles pertaining to OH amongst ENT doctors.	Both this study and online literature suggests that OHs are prevalent within the UK ENT community. However, studies of higher quality are required to thoroughly investigate the causes and risk factors.

<p>The effect of kinesiotape application on functional performance in surgeons who have musculoskeletal pain after performing surgery [22]</p>	<p>Karatas N, Bicici S, Baltaci G, Caner H.</p>	<p>To evaluate the effectiveness of using Kinesiotape on pain and surgical performance in surgeons with pre-existing MSDs</p>	<p>32 surgeons from a university hospital participated. Pain assessments were logged using a Visual Analog Scale. Owestry Low Back and Neck Disability Indexes were used to assess pain effects on activities of daily living. Control day is a day without application of ²KT. KT is applied on the shoulders and lower back when there is a day of similar surgical load, and the tape remains for a few days.</p>	<p>KT has resulted in significant reduction in neck and back pains, and range of motions have increased.</p>	<p>KT is very helpful in mitigating musculoskeletal injury in surgeons already presenting with MSDs.</p>
<p>Occupational musculoskeletal pain amongst ENT surgeons – are we looking at the tip of an iceberg? [23]</p>	<p>Vijendren A, Yung M, Sanchez J, Duffield K.</p>	<p>To investigate prevalence of work-related musculoskeletal disorders amongst UK ENT surgeons and comparisons with existing literature.</p>	<p>A de novo survey covering questions on work-related MSDs was distributed to the entire membership of ENT-UK electronically. A literature search on the subject was then performed using PubMed, Embase, Medline and Google scholar databases.</p>	<p>24% response rate giving sample size of 323. Work-related MSDs had been experienced by 47.4 % of respondents, of which 44% had to undergo physiotherapy. The literature search identified five related studies, which showed that MSDs are common amongst ENT surgeons.</p>	<p>Despite the scarcity of studies, work-related musculoskeletal disorders are common amongst ENT surgeons in the UK, which highlights the need for greater research beyond survey methodologies.</p>
<p>A Preventive Program for Work-related Musculoskeletal Disorders Among Surgeons [24]</p>	<p>Giagio S, Volpe G, Pillastrini P, Gasparre G, Frizziero A, Squizzato F.</p>	<p>To elicit risk factors for various work-related MSDs and to assess effectiveness of intervention in MSDs reduction for 6 months</p>	<p>141 surgeons participated. After cluster randomisation by surgical division, surgeons were allocated to 2 groups: The control group, and the intervention group. The intervention group had education about ergonomic principles and applied these in the operating room, supervised by a physiotherapist. The groups were followed up at 3 and 6 months.</p>	<p>Both groups had similar demographics and anthropometrics at the start of the study. The intervention group had showed a statistically significant reduction of lower back pain and analgesic consumption at 6 months. They also self-reported an improvement in their quality of life at 3 and 6 months.</p>	<p>Implementation of an education program based on surgical ergonomics and specific physical exercises is effective in reducing MSDs and improves quality of life.</p>

<p>The Impact of the Alexander Technique on Improving Posture and Surgical Ergonomics During Minimally Invasive Surgery: Pilot Study [26]</p>	<p>Reddy P, Reddy T, Roig-Francoli J, Cone L, Sivan B, DeFoor W et al.</p>	<p>To evaluate if adoption of ³AT by laparoscopic surgeons during work will improve posture and surgical ergonomics .</p>	<p>Small sample size of 7 surgeons. Each subject served as their own control. Before intervention, subjects underwent assessment of their posture and laparoscopic skills. They were then given the intervention of education about AT and underwent post-intervention assessment of posture and laparoscopic skills.</p>	<p>Subjects showed both objective (ergonomically) and subjective improvements to their posture and an improved ability to complete assessments.</p>	<p>AT education has the potential to improve surgical ergonomics. Further studies of AT are warranted to validate the benefits for surgeons.</p>
<p>Do Micropauses Prevent Surgeon's Fatigue and Loss of Accuracy Associated With Prolonged Surgery? An Experimental Prospective Study [27]</p>	<p>Dorion D, Darveau S.</p>	<p>To evaluate the effectiveness of ⁴MPs in preventing muscular fatigue on surgeons during long surgeries.</p>	<p>16 surgeons participated. Surgeons were tested three times: once in a control situation before surgery and twice after a prolonged, reproducible operation, one of these with formal MP the other without. Muscular fatigue was tested by holding a 2.5-kg weight as long as possible with a stretched arm. Accuracy was evaluated measuring the mistakes made when following a predetermined path on a board., any discomfort was measured by visual analogue scale.</p>	<p>Having MPs prevented the muscular fatigue that would have arisen in surgeons who just underwent long procedures, and reduced the number of errors when doing an accuracy test. Finally MPs had significantly resulted in reduction in physical discomfort in various body parts in surgeons.</p>	<p>MPs have the potential to improve muscle fatigue for surgeons during long operations.</p>
<p>Intraoperative "Micro Breaks" With Targeted Stretching Enhance Surgeon Physical</p>	<p>Park A, Zahiri H, Hallbeck M, Augenstein V, Sutton E, Yu D et al.</p>	<p>To assess the effect of ⁵TSMBs on pain, fatigue, physical functions, and mental focus of surgeons during</p>	<p>66 participants were recruited, including surgeons and assisting staff from four medical centres. They were assessed using standardised questionnaires regarding musculoskeletal pain and performance over</p>	<p>TSMB improved surgeon post-procedural pain scores in various regions throughout the body. Surgeons self-reported improvements in physical performance and mental focus and respondents planned to</p>	<p>Intraoperative TSMB is a novel method of reducing surgeon musculoskeletal pain and increasing mental focus.</p>

Function and Mental Focus [28]		surgery.	two days, one as a control without intervention, the other including TSMB at 20 to 40-minute intervals throughout each surgical case	continue TSMB. Traditionally, surgeons either changed positions or took breaks to mitigate MSDs.	
Evidence-based intraoperative microbreak activities for reducing musculoskeletal injuries in the operating room [29]	Coleman Wood K, Lowndes B, Buus R, Hallbeck M.	To create an exercise set of microbreak activities for MIS surgeons to perform intraoperative in order to reduce work-related MSDs.	Authors used principles of guideline development to identify areas of concerns highlighted by practitioners and the literature, ranked them in terms of severity, compared potential solutions to them and created an exercise set incorporating these solutions.	Specific problems highlighted to overcome were: 1) posture correction; 2) normalisation of tissue tension and soft tissue mobility/gliding; and 3) relaxation/stress reduction. The study gave examples of how problems in a body area can be addressed by the solutions ranked the highest. On average, these activities only take one minute to perform.	By incorporating clinical and ergonomic expertise, it is possible to create an exercise of intraoperative microbreaks.
Ergonomics in the Operating Room: Protecting the Surgeon [33]	Rosenblatt P, McKinney J, Adams S.	To identify aspects of an operating theatre environment and describe common ergonomic errors in surgeon posture during laparoscopic and robotic surgery.	A video article was created based on clinical experience and a review of the literature.	Aspects identified in the theatre that can be modified include the display monitor height, table height, use of arm boards, and foot pedal placement. Literature has identified lack ergonomic awareness among surgeons, and the study identified errors in forward head posture, shoulder elevation and weight bearing asymmetry as common problems faced by surgeons.	Proper theatre setups, posture positioning, awareness and readjustments are necessary components for reducing long-term MSDs.
Feasibility and Acceptance of a Robotic Surgery Ergonomic Training Program. [34]	Franasiak J, Craven R, Mosaly P, Gehrig P.	To evaluate if the application of an evidence-based ET program into surgeon's training is both feasible and	A two-part survey was conducted. The first survey assessed musculoskeletal strain using the standardised Nordic Musculoskeletal Questionnaire. Participants were then given the option to participate in ET session. ET was	Sample size of 42 surgeons. 45% experienced MSD from performing robotic surgery and 26.3% reported persistent strain. All surgeons who participated in the personal ET found it helpful and felt formal ET should be standard.	Evidence-based ET was easily implemented, and well accepted by the robotic surgeons. A larger intervention study is needed to analyse effectiveness of this new training program.

		accepted.	developed from Occupational Safety and Health Administration guidelines and by an engineer experienced with health care ergonomics. After ET, a follow-up survey were completed.	88% changed their practice as a result of the training, and 74% of those reporting strain noticed a decrease in strain after their ET.	
Ergonomic hazards in otolaryngology. [35]	Vaisbuch Y, Aaron K, Moore J, Vaughan J, Ma Y, Gupta R et al	To confirm the presence of MSDs experience using a validated score system, and to evaluate ergonomic knowledge of otolaryngologist surgeons	Using the ⁸ REBA score system to identify ergonomic hazards, the author conducted intraoperative observations of the surgeons. Surgeons had given a separate survey regarding current MSDs and prior ergonomic knowledge.	70 surgeons participated. 72.9% of surgeons suffered from back pain, cervical being the most common location, which corresponded to the REBA score. Only 24% of surgeons had any prior ergonomic training or education.	Musculoskeletal pain induced by poor ergonomics are common among otolaryngologists and surgeons lack ergonomic knowledge to change their workplace setup.
Safety, hazards and ergonomics in the operating room. [36]	Matern U, Konecny S	To elucidate potential areas for ergonomic improvement in the operating theatre.	A 5-part survey was given to surgeons working in German hospitals, gathering data on 1) demographics, 2) Spatial conditions in theatre, 3) Theatre equipment, 4) Working posture and 5) Individual preferences when working in the operating theatre.	425 questionnaires were generated. Many surgeons had concerns with the foot stand, patient positioning, and various equipment handling and admitted to a degree of musculoskeletal discomfort. 97% of the surveyed surgeons see ergonomic improvement in the operating room as necessary.	The results showed many potential areas for ergonomic improvement and calls for future collaboration between healthcare and engineering to develop more ergonomic theatre rooms.
The Current State of Surgical Ergonomics Education in U.S. Surgical Training. [37]	Epstein S, Tran B, Capone A, Ruan Q, Fukudome E, Ricci J et al.	To gather data of surgical ergonomics education in the United States.	A de novo questionnaire was distributed to program directors from 14 surgical and interventional medical specialties, gathering data about the use of formal or informal ⁹ SEE in their programmes.	130 questionnaires were completed. 1.5% of directors provided formal SEE and 25.4% provided informal SEE in their specialty program. Two programs discontinued SEE due to lack of evidence-based guidelines. However,	SEE is hardly present in medical training programs. Even though SEE is viewed as an essential tool for reducing work-related MSDs, lack of evidence-based clinical data makes SEE implementation

				trainees felt that learning surgical ergonomics skills was a worthwhile time investment in 100% and 76.7% of current formal and informal SEE, respectively.	unfeasible.
ErgoPART: A Computerized Observational Tool to Quantify Postural Loading in Real-Time During Surgery. [38]	Zhu X, Yurteri-Kaplan L, Cavuoto L, Sokol A, Iglesia C, Gutman R et al.	To develop and evaluate the effectiveness of an ergonomics analysis tool in tracking real-time postural data of surgeons.	Software and interface development were completed by the collaboration of surgeons and ergonomics researchers. A preliminary assessment was conducted during one vaginal surgery involving four observers with varying degrees of ergonomics experience logging non-neutral postural data.	Inter-observer quantitative information gathered for the entire surgery was fairly homogenous, and is available immediately after completion of surgery.	ErgoPART is a promising software in assessing body postures during surgeries ergonomically, and can record various individual, environmental and work factors that can predispose to greater musculoskeletal strain.

¹OH – Occupational-related Hazard

²KT – Kinesiotape

³AT – Alexander Technique

⁴MP – Micropause

⁵TSMB – Targeted Stretching Microbreak

⁶MIS – Minimally Invasive Surgery

⁷ET – Ergonomic Training

⁸REBA – Rapid Entire Body Assessment

⁹SEE – Surgical Ergonomics Education