INTRODUCTION

On average, surgeons spend approximately 2,500 hours working per year, with up to a third of those hours spent in the operating room (OR).\(^1\) This level of activity can take a toll on the surgeons’ musculoskeletal (MSK) system, particularly as a result of prolonged poorly compensated postural load and absence of good ergonomic practice in the OR, with subsequent pain and disability.\(^2,3\) Small repetitive movements maintained for long hours, poor body posture, and ergonomically unfriendly OR infrastructure all contribute to ergonomic hazards. The science of designing a workplace that considers the capabilities, limitations, and characteristics of the worker defines ergonomics.\(^4\)

Surgeons report a high prevalence of shoulder, neck, and back discomfort and pain.\(^5\) Overexertion and overuse are the most common causes of injury to surgeons and the leading reasons for missed workdays.\(^6,7\) As reported by the Bureau of Labor Statistics, in 2011, nearly half of missed workdays resulting from work-related injuries were attributed to overexertion or body motion–related events, with an average cost of $22,300 from lost productivity.\(^7\) Thus, good ergonomics is good economics.

Workplace ergonomics in the OR is not a new concept. Over the past century, several articles have tried to highlight the importance and the risk of OR ergonomics in otolaryngology. A 2016 survey of 377 otolaryngology surgeons in North America found that 63.9% reported work-related MSK symptoms.\(^1\) A similar picture was seen among the 323 otolaryngology surgeons surveyed in the United Kingdom, with 47% reporting MSK disorders.\(^8\) Of those, 85% sought treatment, 23% required time off from work, and 2% retired early. Another study of 126 Canadian otolaryngologists found 97% experiencing some MSK symptoms, and 74% attributed the symptoms directly to work. In this cohort, 23% believed that their symptoms would shorten their careers.\(^9\) In India, 87.7% of surveyed otolaryngologists reported work-related MSK symptoms, and 60% attributed these to poor ergonomics in the OR.\(^10\) Although the prevalence of work-related MSK symptoms...
is consistent across practicing otolaryngologists globally, it is troubling that this rate is significantly higher than the rates reported in the general adult population.11

These studies demonstrate that poor workplace ergonomics is a significant hazard in the field of otolaryngology. Globally, between 47% to 74% of responding otolaryngology surgeons report some degree of pain or discomfort directly attributed to poor ergonomic positioning during work. Currently, ergonomics are poorly incorporated into everyday surgical practice, partially due to a lack of awareness in the field of surgery, with only one-to-two-thirds of surgeons being aware of ergonomics principles,6,12 and a general OR culture of resistance to implementation.12,13 Improvements in surgical ergonomics can potentially alleviate risk factors that lead to MSK injuries and thus enhance the surgeon’s productivity and performance, reduce time off work, prolong surgical careers, and ultimately improve patient care.12,14

Observational tools have been developed to enable quantitative measurement of postural strain and discomfort. These include the Ovako Working Posture Assessment System; Posture, Activity, Tools and Handling analysis; the Rapid Upper Limb Assessment, and the Rapid Entire Body Assessment (REBA). The REBA, originally developed by Hignett and McAtamney in 2000, is a postural tool designed to analyze different types of working postures applicable in healthcare as well as other industries.15 Our study set out to identify the prevalence of physical pain associated with poor ergonomics as observed in the OR and clinic, and the influence of prior ergonomic education on future OR behavior in otolaryngology specialists at Stanford University. Using the previously validated REBA observational tool, our study evaluated the severity of MSK symptoms in the field of otolaryngology.

MATERIALS AND METHODS

Participants

Seventy otolaryngology surgeons, including attending staff, fellows and residents, were asked to participate in the study. The study was approved by the Stanford University Institutional Review Board. During 2016 to 2018, Stanford Health Care, the Environmental Health and Safety Ergonomics Program, and the Department of Otolaryngology at Stanford University Medical Center conducted a preliminary assessment, mapping ergonomic role and challenges along different stations along the surgical patient cycle of care. This process yielded a checklist and emphasized the need to utilize objective measurement.16

REBA

Objective evaluation of ergonomic injury risk was done using the REBA validated ergonomic risk assessment tool.15,17,18 The tool is available as an app, which enabled continuous real-time assessments and documentation of the risk of ergonomic injury. A score of 3 or less is low risk, 4 to 7 medium risk, 8 to 10 high risk, and 11 or greater very high risk. The observations were conducted in the OR over several months and included a range of surgical postures such as seated microscopic, seated robotic, standing open, and standing endoscopic. A certified professional ergonomist conducted REBA observation. Surgeons were observed on several separate days and during multiple time points throughout a procedure. A minimum of three evaluations were recorded during each operation and then averaged. Observed surgeons’ postures were matched to the drawings on the REBA app. Although attending surgeons were the primary focus of the study, we also analyzed residents and fellows. Each time point received an individual REBA score.

Survey Development and Dissemination

Based on the OR and clinic observations and previous ergonomic literature, the online software SurveyMonkey (Palo Alto, CA) was used to generate a 14-question survey assessing the incidence of work-related MSK, awareness and utilization of ergonomic principles, and aids and prior ergonomic training (see Supporting Information, Appendix 1, in the online version of this article). The survey was distributed by e-mail to the entire faculty and surgical trainees of the Department of Otolaryngology at Stanford Medical Center, and was available for 3 weeks. During this period, a reminder e-mail was sent at the end of week 1. Responses were collected and analyzed upon the closure of the survey.

Statistical Analysis

Statistical analysis was completed using SAS 9.4 (SAS Institute, Cary, NC). Categorical variables were analyzed using $\chi^2$ tests when the number of subjects in every cell was five or more, or Fisher exact tests when the number of subjects in a cell fell below five. A $P$ value of <.05 was considered to be statistically significant. Only statistically significant $P$ values were reported.

RESULTS

The response rate for our survey was 68.6% ($n = 48$ out of 70). Of the 48 surgeons who participated in the study, 15 (31.2%) were female and 33 (68.8%) were male. Years of surgical experience was proportionally distributed amongst the responders. Of the participants, years performing surgery were distributed as follows: 15 (31.2%) were in their initial training years (<5 years), eight (16.7%) had between 5 and 10 years, nine (18.8%) had between 11 and 20 years, 10 (20.8%) had between 21 and 30 years, and six (12.5%) had >30 years of surgical experience.

Postural-Related Physical Impact

A total of 35 (72.9%) responders reported significant discomfort during surgery. Over half of the responders assumed a standing position during surgery ($n = 25$, 58%), especially during open surgical technique. None of the surgeons assumed a standing position during microscopic surgery, whereas endoscopic procedures were done in both the standing ($n = 5$) or seated position ($n = 2$). The most common area of MSK discomfort was in the cervical spine, both in the standing ($n = 12$, 25%) and seated ($n = 3$, 6.3%) position (Fig. 1). Discomfort in both the cervical and lumbar areas were high in the standing position ($n = 9$, 18.7%). Limb pain was similar in both seated ($n = 3$, 6.3%) and standing ($n = 3$, 6.3%) positions. There were 13 (27.1%) participants who reported no pain, and interestingly, this did not appear to be associated with years of surgical practice. Standing during surgery was the activity most associated with back pain, occurring in 21 (43.8%)
participants, and was significantly associated with more cervical pain \((P = .034)\) when compared to pain reported in other locations. Other activities that contributed to back pain were sitting during surgery \((n = 6, 12.5\%)\), sitting in the clinic \((n = 5, 10.4\%)\), standing in the clinic \((n = 1, 2.1\%)\), and other not otherwise specified \((n = 7, 14.6\%)\). Eleven \((22.9\%)\) participants reported that none of the listed activities caused them back pain.

When asked about the frequency of pain, the majority of the surgeons experienced pain during work either less than once per week \((n = 16, 33.3\%)\) or less than two times per week \((n = 13, 27.1\%)\). A small number of responders \((n = 7, 14.6\%)\) reported having pain three or more times per week. The presence of MSK pain was seen in 14 out of 15 \((93.3\%)\) surgeons with less than 5 years of training, five out of eight \((62.5\%)\) surgeons with 5 to 10 years of experience, five out of nine \((55.5\%)\) from the group with 11 to 20 years of practice, eight out of 10 \((80.0\%)\) in those with 21 to 30 years of training, and in three out of 6 \((50.0\%)\) in those with >30 years of training. The average severity of the back pain during surgery or in the clinic was 2.2, using a scale where 0 equals no pain and 10 equals the most severe pain imaginable. The peak average severity of back pain was 3.3.

**Impact on Work**

Approximately half of the responders \((20, 52.6\%)\) stated that the associated MSK pain did not affect their work, whereas 14 \((36.8\%)\) reported only a mild affect. A few were affected moderately \((7.9\%)\) or severely \((2.6\%)\), and 10 participants did not respond to this question. Surgeons were also affected outside of work, with 15 \((37.5\%)\) mildly and 10 \((25\%)\) moderately affected by MSK pain. The remaining 15 \((37.5\%)\) reported no affect with eight participants choosing not to respond.

**Prior Ergonomics Training and Infrastructure**

Forty-five \((94\%)\) responders completed questions on ergonomic knowledge. Thirty-one \((75.6\%)\) surgeons had no prior training in ergonomic \((Fig. 2)\). When asked whether the surgeon had access to ergonomic pieces of furniture in the OR, clinic, or office, 21 \((46.7\%)\) reported access to adjustable surgical chair/stools with armrests. Additionally, 11 \((24.4\%)\) had an ergonomically equipped chair/stool in the outpatient setting, with the rest \((13, 28.9\%)\) having their office set up with either an ergonomic office desk or desk chair.

**Intraoperative Objective Assessment of Ergonomic Hazard**

To objectively assess OR ergonomics, the REBA score was used to evaluate a surgeon’s risk of injury. The head and neck position was evaluated first \((Fig. 3)\). As seen in the figure and recorded in the app, the surgeons head is tilted to one side and flexed forward \((Fig. 3A)\). The trunk is relatively straight with a slight side bend. The legs are straight and the feet are flat on the floor. The force exerted in this case, is less than 11 pounds, without any other qualifiers. (Force exerted was estimated by the ergonomist after discussion with the surgeon, and in this example, <11 pounds was used given standardized technique.) The surgery took approximately 2 hours. The total REBA score for this part of the evaluation, using the app, can be seen in Figure 3B. Next, the upper extremity is evaluated \((Fig. 3C)\). As can be seen, the surgeon’s upper arm is raised and abducted at the shoulder. The lower arm is tilted downward and flexed at the elbow toward the midline. Wrist position is not visible on a static image, but can be ascertained in the OR. Finally, the activity score, which accounts for the length of time in a position and the repetitiveness of activity, is given in Figure 3D. During this evaluation, there were no rapid swings of position. The final REBA score for our surgeon’s evaluation was 8, indicating a high ergonomic risk and leads to a recommendation to investigate and implement change \((Fig. 3E)\).

Table 1 summarizes the REBA score for different surgeries based on whether the surgeon was sitting or standing. The observed REBA risk scores varied between
DISCUSSION

Many otolaryngologists experience MSK pain and discomfort due to their surgical practice, which leads to missed workdays and potentially earlier retirement. Although our study of otolaryngologists confirmed the widespread nature of work-induced pain, it also found that the pain from surgical practice affects other aspects of a surgeon’s life. Importantly, our study found that more than 70% of surgeons had no ergonomic training. A survey of American pediatric otolaryngologists reported that 62% of practitioners experience pain or discomfort attributed to their surgical practice, but only 31% of the practitioners were aware of ergonomics. Similar rates were reported by a large cohort of otolaryngologists from North America, which also found only a third of practitioners had knowledge of ergonomics.

A surprising finding of our study was that both the residents and attending physicians had similar locations and severity levels of MSK pain, with the REBA scoring system finding similar scores. This suggests that ergonomics may not improve with experience and indicates that the problem starts early on in a surgical career and likely persists without intervention. Supporting this finding is a recent study, which found that the majority of the responders (63%) initially experienced MSK symptoms in their training years. Otolaryngology residents in the United States spend an average of 80 hours a week in the hospital, with 26 of those hours in the operating room. Although ergonomic injuries usually accrue over time, our study suggests it does not take long to develop MSK pain. A recent study in otolaryngology residents demonstrated that 76.6% of residents experience some form of MSK pain or discomfort, with 6.4% missing days from residency and 16.3% needing to stop operating during surgery due to the symptoms. In our cohort, 93.3% of surgeons in their training years (<5 years of training) reported MSK symptoms. This highlights the vital need for implementing ergonomics training as part of early residency curriculum.

To date, multiple studies of ergonomics-related MSK symptoms in the field of otolaryngology have focused on the high percentage of surgeons affected. Unique to our study is the addition of objective observation of poor posture in the operating room, which directly correlates with ergonomic hazard. The use of the REBA score has highlighted two important factors. The first is the most prevalent high-risk posture relates to the cervical angle, especially in standing, open surgery. In our cohort, the standing position was significantly associated with cervical pain ($P = .034$). Several other surveys of otolaryngology surgeons reported on neck pain as being most common MSK strain area during the surgery. Secondly, standing for extended periods of time (>30 minutes) almost always elevated the REBA risk score into the high-risk category. Thus, our study reveals that standing as compared with seated surgery, regardless of the type, presents the most risk as identified by the REBA score ($P < .001$) and confirmed by our survey results. Thirdly, the seated operation almost always produced a lower REBA score, as it removed much of the static exertion. Again, these findings were also reflected in our survey data. Additionally, most attendings and residents/fellows displayed medium to high ergonomic severity risk, suggesting that urgent work to address this problem is required.

The REBA observation also suggests that the risk of MSK symptoms can be reduced by optimizing the OR and clinical setup. From an ergonomics perspective, it is almost always better to adjust the furniture or patient rather than yourself. As otolaryngology surgeons, we are often taught to move around the patient rather than adjust the patient. Similarly, even when the surgeon makes adjustments to the tables and stools, many do not adjust to the extreme required, thus forcing the surgeon...
to adopt an uncomfortable posture, often subconsciously, such as standing on a step stool, flexing the cervical spine, or crouching or slouching in the chair, all of which are conceptually and ergonomically inappropriate. Equipping ORs, offices, and clinics with ergonomic furniture can be one area of priority for preventing MSK injury. For example, in the ideal operating room, furniture for seated otolaryngology procedures includes a surgical table that has a height range of 63.5 to 125.7 cm and a surgical stool with a height range of 50.8 to 72.4 cm. This versatility in height adjustment is optimal for a diverse range of physician heights. Our findings indicate that most of our responders have access to the necessary furniture, which suggests training and implementation of ergonomic principles are key limiting factors.

Fig. 3. Using the REBA app for intraoperative observation of ergonomic risk assessment severity. (A) As an example, a photograph of the surgeon’s intraoperative position was taken and assessed, and the surgeon, pictured in the middle, was evaluated. (B and C) REBA score for limbs as well as for the head and neck evaluation using the app. (D) Activity score. (E) The REBA final risk level assessment score and recommendation, provided at the end of the assessment where the app color represents severity risk as follows: green = low risk (3 or less), yellow = medium risk (4–7), orange = high risk (8–10), red = very-high risk (11 and above). REBA = Rapid Entire Body Assessment.
There are some limitations to this study. First, this study had a small sample size and was from a single institution, which may limit its generalizability. However, we had an excellent response rate of 68.6%, which compares very favorably to the literature.\(^1,6,10,19,20,22–24\) Additionally, assessment of the REBA score can be subjective, as most postural positions are scored based on both an angular and a time factor. A static picture can be used to accurately measure an angle, but does not capture the length of time a position is maintained or how many repetitions per minute occurred. REBA does not account for time and lacks a way of quantifying time as a primary factor in determining injury risk. The activity score in Figure 3D inquires if a body part holds a static posture for more than 1 minute. The REBA also provides a global score, but does not capture the dynamic of poor posture, relying on general frequent observations, which may mean that some postural components are missed during the analysis. Furthermore, predisposing factors such as, but not limited to, previous sports injuries, ophthalmologic amblyopia/disconjugate gaze compensation, and height limitations may potentially have contributed to differences in positioning of the body during surgery. Our survey did not evaluate a thorough assessment of these factors. Nevertheless, the goal of our article was to look at the position assumed (either standing or sitting) and its effect on ergonomic stress. Future studies are needed to evaluate possible intervention, specifically aimed at training and implementation of ergonomic principles and equipment, with a focus of standing surgery and cervical angle.

CONCLUSION

We found a low rate of ergonomic training with high levels of MSK strain reported subjectively and observed objectively, but with good access to ergonomic furniture. This emphasizes a pressing need to bridge the gap between availability and use. As with other areas of healthcare, awareness and prevention are the key to improving outcomes. Future studies should look at the efficacy of implementing interventionial programs and their effect on surgeons’ practices and MSK pain.

BIBLIOGRAPHY

8. Vijendren A, Yung M, Sanchez J, Dufffield K. Occupational musculoskeletal pain amongst ENT surgeons—are we looking at the tip of an iceberg? J Laryngol Otol 2014;130:490–496.

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