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Journal

Laryngoscope Investigative Otolaryngology, 7(5)

ISSN

2378-8038

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Publication Date

2022-10-01

DOI

10.1002/liv.2.901

Peer reviewed

ORIGINAL RESEARCH

Surgical ergonomics: Assessment of surgeon posture and impact of training device during otolaryngology procedures

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Abstract

Objective: To identify factors associated with cervical-thoracic spine posture in otolaryngology surgeries and evaluate the efficacy of a commercially available posture-training device in enhancing surgeon ergonomics.

Methods: Over 3 months, neck and spine posture from individuals performing otolaryngology surgeries was recorded using UpRight Go 2™. Average baseline posture was first recorded and biofeedback was later introduced to attempt to correct posture. The proportion of time spent in upright/neutral cervical-thoracic spine posture was correlated with surgeon and procedure characteristics and compared to proportion of upright posture time after biofeedback intervention.

Results: The proportion of upright operating time was significantly different between procedure subtypes and surgical approaches with best performance in rhinology procedures and worst performance in head and neck surgeries (90% vs. 62%; both $p < .001$). Female gender, shorter stature, and use of sitting stools were associated with greater proportion of surgery spent upright (all $p < .05$). Loupes use was associated with less time in upright posture ($p < .001$). With biofeedback intervention, 8 of 10 subjects demonstrated an average of 5% improvement in operating upright, with most improvement found when performing laryngology procedures (7%) and least improvement in head and neck procedures (2%).

Conclusions: While surgeon posture varies across otolaryngology surgeries, sitting and minimizing the use of loupes may help promote a more ergonomic operating environment and improve surgeon posture. Although the efficacy of biofeedback intervention from a commercially available posture-training device differs among otolaryngologists, exploration of alternative interventions and incorporation of an ergonomics curriculum is warranted to address postural issues experienced by many surgeons.

Level of Evidence: 3.

KEYWORDS

ergonomics, operating room, otolaryngology, posture, surgery

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1 | INTRODUCTION

Surgeons are at high risk for various work-related musculoskeletal (MSK) disorders due to frequent long hours of sustained and often suboptimal posture, repetitive movements, and prolonged exertion while operating.¹ Such disorders have contributed to not only reduced surgeon quality of life, but also diminished work productivity and even early retirement, making it imperative to seek strategies and tools to prevent and reduce their development.^{2,3} Importantly, among this workforce, multiple studies suggest up to a 74% prevalence rate of work-related MSK symptoms in otolaryngologists globally, making otolaryngology one of several medical specialties with highest risk for development of work-related MSK disorders.¹⁻⁶

Within otolaryngology practitioners, the most commonly reported sites of pain are the cervical spine and neck followed by the back and shoulder regions.⁷⁻⁹ These repetitive strain injuries commonly arise from engaging in awkward postural positions to work in narrow surgical fields inherent to the head and neck region. Other reported factors associated with work-related MSK symptoms in this group include standing while operating, using headlamps or surgical loupes, operating without a monitor in endoscopic sinus surgeries, and performing microlaryngeal surgeries for greater than 30 min or without arm support.¹⁰⁻¹²

While the hazards of improper ergonomics in the operating room have started to gain attention recently, most studies of ergonomics in otolaryngology have been conducted via survey methods with limited quantitative measurements. Even then, the currently published quantitative assessments have used intricate methods of measurement or observational methods.^{8,9,12} Despite improved posture being shown to help with management of MSK pain symptoms when implemented with workplace interventions and an increase in general fitness, no studies to date have directly quantified surgeon posture.¹³ Furthermore, for the surgeon seeking to improve their ergonomics in the operating room, there remains a need to clearly identify targets for improvement and have the tools available to properly meet these goals.

Therefore, the primary aim of this study is to quantify posture through use of a commercially available posture-training device for a variety of otolaryngology procedures, and identify procedures and areas of surgery at greatest risk of poor ergonomics. In addition, this study evaluates the efficacy of using biofeedback from this device as an intraoperative intervention in improving surgeon posture. Based on the current literature and anecdotal stories, we hypothesize risk factors for poor ergonomics to include taller stature, the use of equipment such as headlamps/loupes, and surgeries done in an open compared to less invasive approach. Biofeedback will raise surgeon awareness on their own ergonomics to reduce time in poor posture while operating.

2 | MATERIALS AND METHODS

An institutional review board (IRB)-approved prospective study (#200622) was conducted at a single tertiary referral center and academic institution from June to September 2021. Attending surgeons,

fellows, residents, and medical students rotating within the Department of Otolaryngology were invited to participate in the study. Informed consent was obtained from each participant prior to participation in the study. Surgeries were classified by procedure subtype (head and neck, rhinology, laryngology, otology/neurotology) and surgical approach (open, endoscopic, microsurgical, and robotic).

2.1 | Data collection

A commercially-available posture training device, UpRight Go 2™ (Tel Aviv, Israel), was used off-label to measure the amount of time participants spent upright/neutral or slouched/non-neutral during each surgical case. The device contains built-in sensors with a gyroscope to detect posture in real-time and has the capacity to send biofeedback in the form of a gentle vibration if posture is deviated from a preset level from neutral position. All posture data from each individual is then automatically recorded in a smartphone application for detailed statistics and progress tracking.

Prior to the start of each surgical case, the device was placed around each participant's neck just below the prominence of the spinous process of the seventh cervical vertebrae. The device was then calibrated to each participant's ideal, achievable, upright/neutral cervical and thoracic spine position (Figure 1). The threshold for slouched/non-neutral posture was set at a motion range setting of six on the device, which is approximately 77° of deviation from the initially calibrated neutral cervical and thoracic spine position.

During Phase I, each device operated under tracking mode. Tracking mode continuously records each participant's cervical and thoracic spine posture without feedback. The amount of time spent in the upright/neutral and slouched/non-neutral positions was recorded while each participant was sterilely gowned for the procedure. Each participant wore the device for a minimum of eight surgical cases (approximately 20 h of operating time) during this phase of the study to establish an average individual baseline posture.

During Phase II of the study, the device operated under training mode. In addition to monitoring each participant's cervical and thoracic spine posture, training mode sends biofeedback signals by vibration after sensing sustained slouched/non-neutral posture for a minimum of 30 s. Similar to Phase I, participants in Phase II wore the device for a minimum of eight surgical cases (approximately 20 h of operating time). Each participant's average postural response after biofeedback was calculated and compared to the average baseline posture of Phase I.

2.2 | Variables

Surgery characteristics were recorded for each surgical case, including: procedure subtype, surgical approach, surgeon role (i.e., lead, assisting), table height, frequency of table height adjustment, and use of sitting stools, step stools, headlamps, and/or loupes for >50% of operating time. Individual participant data was collected including

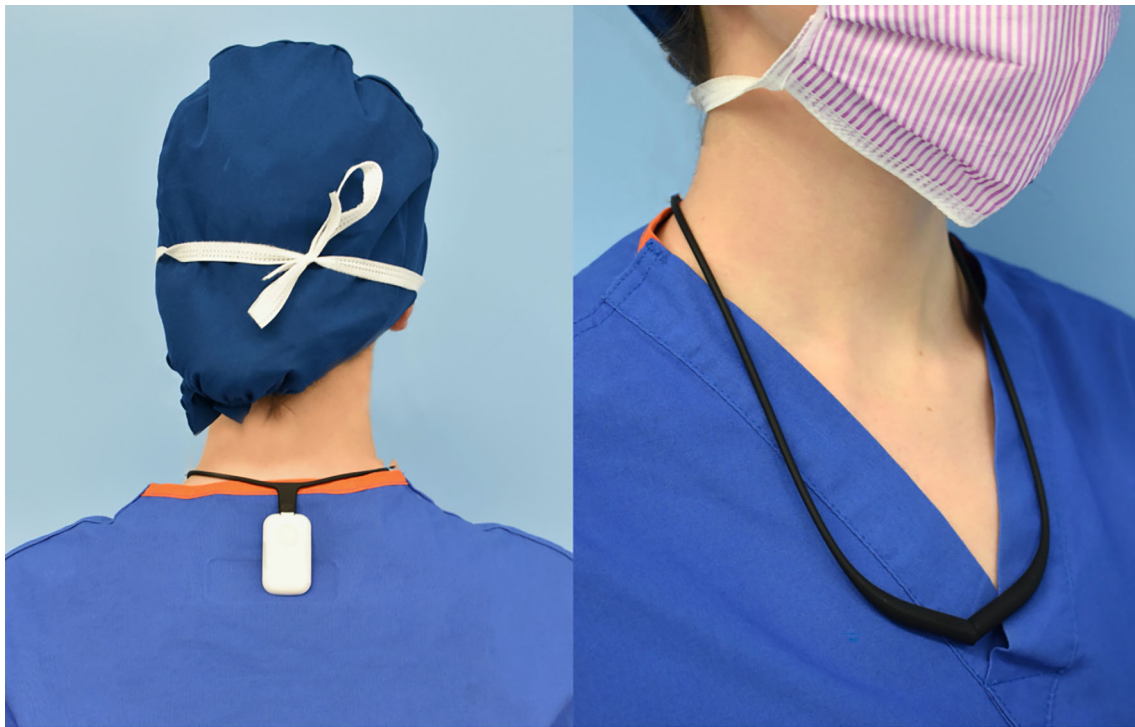


FIGURE 1 Posture-training device on participant. The device is placed between the base of the cervical and thoracic spine and against the skin to maximize detection of postural changes and avoid breaking the sterile field (pictured here over clothing to demonstrate approximate positioning of device).

gender, height, and level of training. The most frequently used height of the operating table was recorded following each surgical case and the ratio of table height to participant height for each participant was calculating by dividing table height by each participant's height.

2.3 | Statistical analyses

Data analysis was performed in IBM SPSS statistics for Windows, version 26 (IBM Corp., Armonk, NY). The proportion of time spent in upright/neutral and slouched/non-neutral positions were used to compare time spent upright versus slouched between individuals performing surgeries of different lengths. ANOVA were used to determine the effects of different surgery characteristics and individual factors on the proportion of time spent in upright/neutral posture while operating at baseline, followed by multivariate ANCOVA (blend of ANOVA and regression) with Bonferonni adjustment to identify interactions between variables with significant associations. Pearson correlations analyzed relationships between participant height, table height, frequency table height was adjusted, and proportion of operating time spent upright. The proportion of operating time spent in upright/neutral posture before and after introduction of the device biofeedback signals was compared using student's *t* test for changes within each participant and paired *t* test for changes within procedure subtypes. All results were considered statistically significant at a calculated probability (*p*) value less than or equal to 5%, or $p \leq .05$.

3 | RESULTS

3.1 | Participant and surgery characteristics

18 medical providers participated in this study: seven attending surgeons (39%), one fellow (6%), seven resident physicians (39%), and three medical students (17%) (Table 1). The 10 of these 18 participants (five attending, one fellow, and four residents) received device biofeedback intervention. Of all participants, there were 14 males (78%) and 4 females (22%). The mean age of all participants was 34 ± 11 years. Regarding height, one participant was $<5' 2''$, 5 participants were between $5' 2''$ and $5' 9''$, and 12 were participants were $5' 10''$ or taller.

A total of 154 procedures were recorded: 47 head and neck (31%), 39 rhinology (25%), 26 laryngology (17%), and 41 otology/neurotology (27%). Regarding surgical approach, there were 62 open (40%), 44 endoscopic (29%), 45 microsurgical (29%), and 3 robotic (2%) cases. The use frequency of sitting stools, step stools, headlights, and loupes used in each procedure subtype and surgical approach are summarized in Table 2. The average duration of operating time in each case was significantly different between procedure subtypes ($p < .001$) but not surgical approach ($p = .29$).

3.2 | Variables contributing to posture while operating

The proportion of operating time-spent upright/neutral was significantly different between groups based on gender, height, procedure

subtype, surgical approach, sitting versus nonsitting, and use of loupes versus no loupes (Table 3). Females spent an average of 87.5% operating time upright while males spent an average of 72.5% operating time upright ($p = .002$). Participants with shorter stature (<5' 10") had an average of 85.7% operating time upright versus 71.3% in participants 5' 10" and above ($p = .006$).

Head and neck ablative surgery had the smallest average proportion of operative time spent in the upright position (54.9%), while rhinologic surgery had the greatest proportion of time in the upright position (90.0%, $p < .0001$). For surgical approach, open approaches averaged the smallest proportion of time in upright position (57.3%), compared to endoscopic (90.0%), microsurgical (89.3%), and robotic cases (87.4%) ($p < .0001$). The average

proportion of upright time was greater with the use of sitting stools versus without (89.1% vs. 72.9%, $p = .05$). The average proportion of upright time was less with loupes versus without (49.9% vs. 81.5%; $p < .001$).

After adjusting for interaction between significant values using ANCOVA with Bonferroni adjustment, procedure subtype ($F_{5,143} = 3.83$, $p = .04$), surgical approach ($F_{3,145} = 8.03$, $p < .001$), and loupes use ($F_{1,147} = 9.07$, $p < .001$) remained statistically significant. Gender ($F_{1,147} = 2.92$, $p = .06$), height ($F_{2,146} = 3.03$, $p = .06$), and the use of sitting stools ($F_{1,147} = 0.85$, $p = .33$) lost significance upon adjustment. The average proportion of time spent in upright posture did not significantly differ between participants of different training levels ($p = .31$), role in surgery ($p = .87$), step stool use ($p = .48$), and headlight use ($p = .31$).

Pearson correlations demonstrated that participant height and the number of times the operating table height was adjusted negatively correlated with the proportion of upright operating time ($R = -0.24$, $p < .01$, both values) (Table 4). Participant height also negatively correlated with the table height to participant height ratio ($R = -0.28$, $p = .006$). The table height to participant height ratio positively correlated with the frequency of table height adjustment ($R = 0.25$, $p = .02$).

TABLE 1 Participant demographics

Characteristics	Total (%)
Participants	18
Level of training	
Attending	7 (39%)
Fellow	1 (6%)
Resident	7 (39%)
Medical student	3 (17%)
Gender	
Male	14 (78%)
Female	4 (22%)
Height	
< 5' 2"	1 (6%)
5' 2"–5' 9"	5 (28%)
5' 10" and above	12 (67%)

3.3 | Impact of biofeedback signals on improving posture

With the device biofeedback intervention, 8 out of 10 participants spent a greater average proportion of operating time in upright cervical/thoracic spine posture, with an average of 5% and up to 11% improvement compared to their average proportion of time spent in upright posture at baseline without device intervention (Figure 2A).

TABLE 2 Number of cases, frequency of operating tools used, and average operating duration by surgery type and approach

	Total number of cases	Sitting stool	Step stool	Headlight	Loupes	Average duration (minutes)	p value ^a
Total	154						
Procedure subtype							
Head and neck							
Ablative	33	12.1%	6.1%	9.1%	45.5%	90.8	
Reconstruction	14	0%	0%	28.6%	50%	116.1	<.001
Rhinology	39	0%	0%	7.7%	0%	132.7	
Laryngology	26	57.7%	0%	57.7%	15.4%	52.0	
Otology and neurotology	41	90.2%	0%	0%	0%	102.4	
Surgical approach							
Open	62	17.7%	3.2%	35.5%	40.3%	91.2	
Endoscopic	44	2.3%	0%	6.8%	4.5%	122.3	.288
Microsurgical	45	91.1%	0%	0%	0%	101.3	
Robotic	3	100%	0%	0%	0%	80.7	

^aANOVA performed to assess for differences in operating time between procedure subtypes and surgical approaches.

TABLE 3 Impact of participant and surgery characteristics on posture

Characteristic	Unadjusted ^a		Adjusted ^a	
	Proportion of surgery spent in upright posture (%)	p value	Proportion of surgery spent in upright posture (%)	p value
Gender				
Male	72.5	.002	74.0	.064
Female	87.5		82.6	
Level of training				
Attending	77.4			
Fellow	72.8	.313		
Resident	78.0			
Medical student	64.8			
Height				
<5' 2"	85.7		95.2	
5' 2" – 5' 9"	85.7	.006	71.2	.059
5' 10" and above	71.3		84.1	
Role in surgery				
Operating	74.5	.872		
Assisting	75.2			
Procedure subtype				
Head and neck				
Ablative	54.9		78.0	
Reconstruction	69.2		96.3	
Rhinology	90.0	<.001	70.5	.036
Laryngology	76.8		82.9	
Otology and neurotology	81.9		68.2	
Surgical approach				
Open	57.3		61.4	
Endoscopic	90.0	<.001	85.9	<.001
Microsurgical	89.3		85.6	
Robotic	87.4		89.8	
Sitting stool use				
Sitting	81.4	.054	78.6	.334
Standing	72.9		74.5	
Step stool use				
No step stool	75.8	.480		
Step stool	89.1			
Headlight use				
No headlight	77.0	.306		
Headlight	71.1			
Loupes use				
No loupes	81.5	<.001	79.5	<.001
Loupes	49.9		59.3	

^aANOVA performed in unadjusted (left) and ANCOVA with Bonferroni in adjusted analyses (right).

The average proportion of operating time spent upright improved across head and neck, laryngology, otology/neurotology, and rhinology procedures (Figure 2B). The most improvement was found in

participants when performing laryngology procedures (7%) while the least improvement was noted when performing head and neck procedures (2%).

TABLE 4 Pearson correlations among participant height, operating table settings and posture

	Participant height	Table height: participant height ratio	Number of times table height adjusted
Participant height	1.00		
Table height: participant height ratio	-0.28 ^a	1.00	
Number of times table height adjusted	0.08	0.25 ^a	1.00
Proportion of surgery spent in upright posture	-0.24 ^a	-0.04	-0.24 ^a

^aValue is statistically significant, $p < .05$.

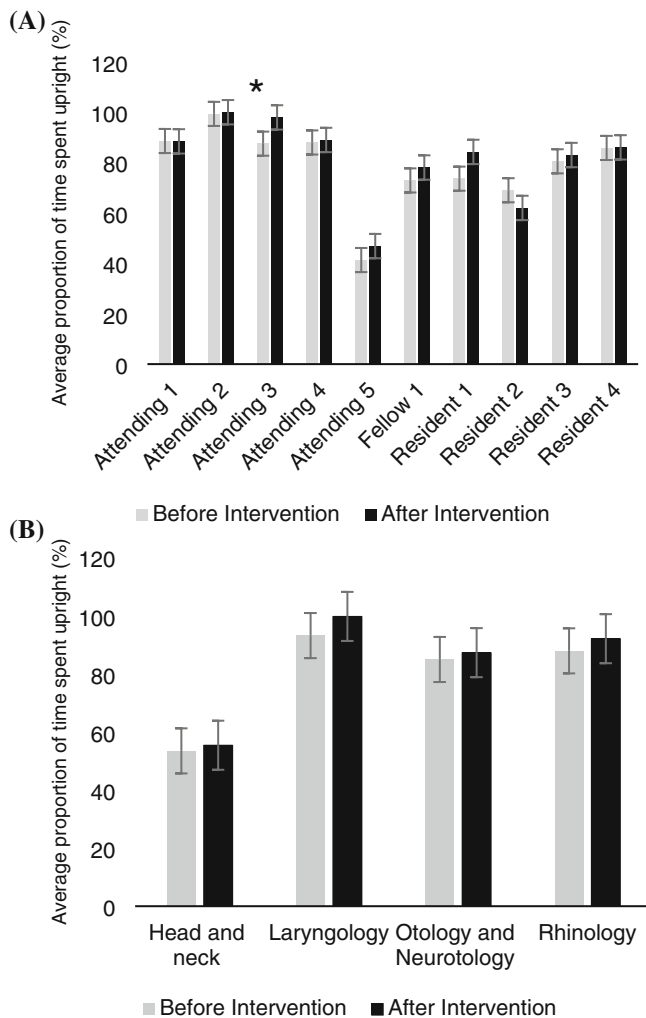


FIGURE 2 Impact of device intervention on posture. Average proportion of time spent upright in (A) all procedures performed by each participant before and after device intervention and (B) all procedures of particular surgery subtype performed by any participant before and after intervention. *denotes statistical significance

4 | DISCUSSION

Previous studies have established a high prevalence of MSK symptoms among otolaryngologists, and some factors related to the development of such symptoms have been identified via survey responses

or observation.^{2,3,8,9,12} Using a novel method of quantifying posture by determining the proportion of time operating within a normal range of postural angles versus a predetermined deviation from neutral, this study found significant postural differences between procedure subtypes and surgical approaches, surgeon gender and height, and the use of operating adjuncts, particularly sitting stools and surgical loupes.

The strongest factors influencing the proportion of operating time spent in upright cervical-thoracic spine posture was procedure subtype and surgical approach. Despite numerous reports of MSK symptoms experienced by rhinologists,^{10,14,15} the overall best posture was found in this group of surgeons. Operating without a monitor has previously been found to positively correlate with MSK symptoms in endoscopic sinus surgeries,¹⁶ which may be reflected in our finding as nearly all rhinology procedures performed at our institution utilize monitors rather than direct visualization through an endoscope. With similar apparatus using microscopes or robotic consoles, it is unsurprising that microsurgical and robotic surgeries were associated with relatively better posture. In contrast, without the availability of such visual displays, head and neck surgeries, a majority performed via an open approach, were associated with the longest duration of poor posture even when other ergonomic measures, such as tucking in patient arms, were taken. Despite finding overall better cervical-thoracic spine posture in endoscopic, microsurgical, and robotic surgeries, it should be noted that prolonged static posture, eye strain, and awkward upper extremity maneuvers often associated with these procedures also contribute to poor ergonomics and potential risk of MSK injuries over time,^{9,17} however, these variables were out of the scope of this study.

Both height and male gender were initially associated with worse cervical-thoracic spine posture while operating, but significance was diminished upon adjusting for other variables. There may be an interaction between gender and height, as males in this study were generally taller than females. Furthermore, two of the four female participants primarily operated in rhinology and otology procedures, which may have acted as a confounder. Nevertheless, surgeon height does influence the ergonomic environment, as the optimal working surface height is relative to the height of the surgeon.¹⁸ An operating table that is positioned too low will result in forward neck and trunk flexion, which associates with pain.^{15,19} Interestingly, our data relating to participant heights and operating table settings demonstrate that table heights did not increase with participant height, implying a lack

of inclination to raise the operating table even with taller stature. Furthermore, the frequency of table adjustment correlated with poor posture, which could suggest that operating tables were adjusted primarily when postural comfort was significantly affected. These findings highlight a lack of ergonomic practice such as adjusting the table or patient rather than oneself and may reflect limited ergonomics education for surgeons.²⁰

While setting an appropriate operating table height while standing certainly promotes better operating posture, the table can be adjusted to only one individual at a time or set to a compromised height for multiple individuals assisting in the procedure. Sitting stools allow surgeons to use less muscular activity to maintain posture while positioned closer to the patient and step stools help mitigate any large height differences between individuals around the operating table. In concordance with other studies,^{8,19} we found the use of sitting stools to correlate with longer time in upright posture, further emphasizing the potential benefit of operating in a seated position if the operating table height cannot be adjusted appropriately for an individual.

In contrast, similar to the findings of other ergonomics literature,^{12,21} we found the use of loupes to negatively impact cervical-thoracic spine posture. Statistically significant differences in posture from headlights use were not detected in our study and may be due to the reduced use of headlights when built-in loupes lights were available. One suggestion made by Rodman et al. to reduce cervical strain created by these equipment is to increase use of operative microscopes, particularly in cases where operative outcomes are not influenced by approach such as in thyroid surgery.¹² Exoscopes, a surgical technological advancement that have gained attention recently, also demonstrates promise in potentially replacing surgical loupes in the future.²² Of note, our study identified head and neck procedures with the poorest cervical-thoracic spine posture and most frequent loupes use, therefore, consideration of using microscopes in lieu of loupes or headlights where possible may be of benefit to the cervical-thoracic spinal health of head and neck surgeons.

Aside from discussion of strategies to limit high-risk maneuvers and positioning in the operating room,^{16,18} there remains a lack of available and convenient interventions that can improve surgeon posture. To our knowledge, our study represents the first to investigate the efficacy of a commercially available posture training device for surgeon posture improvement when performing otolaryngology procedures. While these devices have been shown to reduce neck flexion angles and gravitational moments in office settings,²³ we found minimal improvement in the time spent in upright cervical-thoracic spine posture when utilizing these devices in otolaryngology surgeries. For endoscopic, microsurgical, or robotic cases, this is likely due to an already high proportion of time in upright posture at baseline with little room for improvement. Our data demonstrates that cervical-thoracic spine posture is not the most pressing ergonomic concern in cases done via these surgical approaches, and therefore there may be limited benefit to utilizing posture training devices in these types of surgeries.

Interestingly, despite relatively poor cervical-thoracic spine posture at baseline, posture improved the least after intervention of the

device in open head and neck surgical cases. This may be because poor posture is sometimes the most efficient means to attain sightline of the narrow operative field and windows into the surgical field may precede the possibility of ergonomic adjustment even in the presence of biofeedback warning signals. Meanwhile, though modest, the greatest improvement in posture was seen in laryngology cases. Previously identified risk factors for MSK injury specifically in microlaryngeal surgery include neck flexion and a lack of arm support.¹¹ Use of the posture training device along with ergonomic training may improve the overall posture and potential subsequent incidence of MSK symptoms in the group of surgeons performing these procedures.

Although the incorporation of a posture training device in otolaryngology showed variable improvement in surgeon posture, the capacity to reduce ergonomic hazards with other interventions should be further examined. Anti-fatigue mats have been associated with perception of reduced back pain and ergonomically inappropriate practices (i.e., weight-shifting), while the use of short intermittent intraoperative breaks also allow for relaxation of muscles while operating.²⁴⁻²⁶ Ergonomically designed hand grips and instruments may address upper extremity strain prevalent in minimally invasive procedures.²⁷ Most importantly, ergonomics education can raise awareness and reduce pain-related behaviors and symptoms, yet there remains a lack of training for most at-risk physicians.^{20,28} We show that individuals of different training levels have similar proportions of upright operating time in addition to comparable ergonomic risk identified in previous studies.⁸ MSK symptoms have also been found to be prevalent among otolaryngology residents, with some having to step out of an operation or miss work due to their symptoms.²⁹ This suggests that ergonomic problems can begin during residency or earlier and persist if no interventions are given. Therefore, the development of an ideal ergonomics curriculum during early medical training is warranted with the goal of promoting and reinforcing healthy ergonomic habits. Of interest, Duke Surgery has recently initiated a formal ergonomics program consisting of ergonomics labs with residents, one-on-one observation of chief residents, and coach training for rising chief residents.³⁰

Limitations of this study include a small study sample which may reduce the power of our study. Few female surgeons were available to participate, and weight and BMI were not collected in this study, which may serve as variables influencing posture. The device was also unable to measure shoulder rounding or postural deviations in the lumbar and more superior regions of the cervical spine. Furthermore, the precise magnitude of posture deviation in each individual was not examined and it may be possible that the degree of slouch improved with device intervention without significant differences in proportion of operating time spent upright. Lastly, as the posture device needed to be placed on each individual and calibrated prior to every surgical case, participants may have been subjected to the Hawthorne effect when posture is altered due to awareness of their posture being recorded.

Future studies include examining ergonomics that contribute to increased stress at other areas of the spine and extremities that may be particularly more prevalent in minimally invasive procedures. The

efficacy of other interventions including anti-fatigue mats, ergonomically-designed instruments, and intermittent intraoperative breaks have also yet to be investigated in a quantifiable manner. Additionally, the reversibility of work-related MSK pain and injuries in surgeons have been poorly studied to date and it remains unclear whether certain activities or therapeutics (i.e., acupuncture, yoga) that have benefit for MSK pain in the general population may similarly help reverse/alleviate symptoms for surgeons.^{31,32} For surgeons who have limited ergonomic flexibility due to narrow operative fields including but not limited to those performing head and neck procedures, identifying therapeutic measures is of high importance to help extend career longevity in this workforce.

5 | CONCLUSION

Many otolaryngologists experience work-related MSK symptoms as a result of the poor postural positioning demanded by certain procedures and limited surgical exposure. In certain cases, these injuries may ultimately restrict surgical practice, drive early retirement, and diminish quality of life. Using a commercially available postural measurement device, we identified head and neck ablative procedures as having the greatest proportion of poor posture operative time. Certain interventions, in particular the use of sitting stools and minimizing the use of loupes where possible, may help improve surgeon posture. A biofeedback intervention was of minimal benefit for correcting poor posture in this group of surgeons, however, this intervention may still be of benefit depending on individual sensitivity and type of procedures performed. Regardless, ergonomic education and intervention when possible are warranted for surgeons of all fields and training levels.

FUNDING INFORMATION

The authors have no funding and financial relationships.

CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

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How to cite this article: Leung KL, Segal RM, Bernstein JD, Orosco RK, Reid CM. Surgical ergonomics: Assessment of surgeon posture and impact of training device during otolaryngology procedures. *Laryngoscope Investigative Otolaryngology*. 2022;7(5):1351-1359. doi:[10.1002/lio2.901](https://doi.org/10.1002/lio2.901)