Work-related musculoskeletal disorders in endoscopic sinus and skull base surgeons: an international survey

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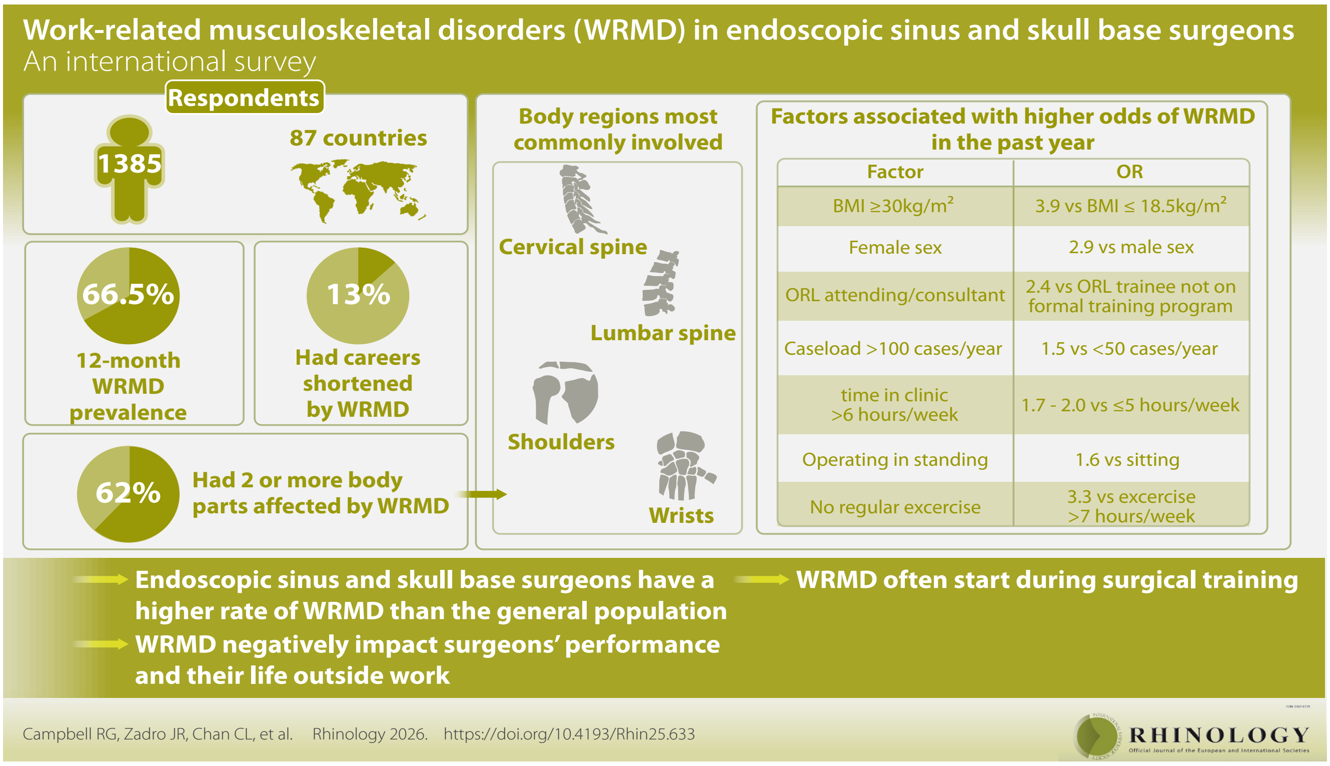

Abstract

Background: Endoscopic sinus and skull base surgeons are at high risk of work-related musculoskeletal disorders (WRMD) due to the unique ergonomic risks inherent in this specialty. These musculoskeletal disorders may negatively impact surgeons and their patients. The primary aim of this international survey was to quantify this problem globally and evaluate its associated factors. **Methods**: A 46-item electronic survey was distributed to endoscopic sinus and skull base surgeons at any career stage via multiple international professional societies. **Results**: We received 1385 responses. The prevalence of WRMD in the previous week and 12 months was 44.2% and 66.5%, respectively. The neck, shoulders, lumbar spine and wrists were the most commonly involved body parts, and most surgeons had symptoms in multiple body parts. Work-related musculoskeletal disorders were reported to negatively impact work, hobbies, activities of daily living and sleep, and to shorten careers in respondents. Factors associated with higher odds of WRMD included female sex, BMI ≥30kg/m^2, being an attending otolaryngologist, having a high surgical and clinic caseload (performing >100 ESSB procedures annually), and operating in standing. Regular exercise (>7 hours weekly) and an endomorphic somatotype were associated with lower odds of WRMD. **Conclusions**: Endoscopic sinus and skull base surgeons have a high prevalence of WRMD. Modifiable risk factors include surgical volume, clinic time, operating position, and regular exercise. We make recommendations to assist in the reduction of WRMD in this population.

Key words: endoscopic sinus surgery, endoscopic skull base surgery, ergonomics, neurosurgeons, otolaryngologists

Introduction

Surgeons are at high risk for developing work-related musculoskeletal disorders (WRMD) [1], which can have both short- and long-term consequences for the surgeon, surgical team and their patients. Musculoskeletal disorders contribute to burnout, reduced quality of life (QoL) and increase the risk of chronic diseases such as cardiovascular disease and cancer [2, 3]. Musculoskeletal disorders impair surgeons' performance, increase errors, and can shorten careers [4-6]. Finally, the economic burden of WRMD in the general population has been estimated to cost up to 10% of GDP per year [7].

Risk factors for WRMD in general include repetitive movements, prolonged, awkward postures, and the subsequent force loading on musculoskeletal structures [8]. The surgical environment encompasses all these risk factors and, in addition, requires the use of one-size-fits-all instruments, advanced hand-eye coordination, extended periods of concentration, a high cognitive load and precise manipulative skills [9].

Otorhinolaryngologists, particularly endoscopic sinus and skull base (ESSB) surgeons, have a high prevalence of WRMD compared to other subspecialties [10]. Endoscopic sinus and skull base surgery requires the surgical dissection to be performed 'out of plane' to the surgeon, as monitors and cameras are used for visualization. This requires the surgeon to combine a two-dimensional image on the screen with the patient's three-dimensional anatomy while performing precise movements in a uniquely anatomically restricted environment. This arrangement creates a disconnect between the visual and motor axes.Without intervention, WRMD in ESSB surgeons are likely to increase as sinonasal diseases, such as chronic rhinosinusitis and allergic rhinitis, are some of the most prevalent chronic medical conditions and are increasing in prevalence [11, 12]. Further, expanded endoscopic approaches to the skull base are becoming increasingly utilised. To date, published literature on WRMD in ESSB surgeons consists mostly of surveys with limited sample size (n = 82–250) [5]. Published prevalence proportions of WRMD among otorhinolaryngologists vary widely from a lifetime prevalence of 43.4% to a point prevalence of 97% [5]. However, few data specific to ESSB surgeons are available. Further, there is limited research on risk factors, prevention or intervention strategies for WRMD in this population. Therefore, a detailed global investigation is needed to more accurately quantify the problem in ESSB surgeons.

Objectives

The primary objectives of this study were to evaluate the international prevalence of WRMD, and to explore associated factors for WRMD, in ESSB surgeons. Our secondary objectives were to evaluate the details of the WRMD (including location, and type of injury), to compare the frequency and symptom severity of body parts involved between males and females, to explore the impact of WRMD on lifestyle and QoL and the WRMD care seeking behaviour. Finally, we assessed the prevalence of ergonomic education and training and any interventions that may reduce WRMD in this population.

Materials and methods

This international cross-sectional survey was approved by the Research Ethics and Governance Office of Sydney Local Health District (X23-0283 and 2023/STE02789).

Survey

An open survey was designed in Research Electronic Data Capture (REDCap), hosted by the University of Sydney (Appendix 1). The survey was based on previously published literature and further developed by an ESSB surgeon and physiotherapist (RGC) in consultation with physiotherapists with expertise in ergonomics, biomechanics and musculoskeletal disorders (EP, MM, JZ, CC, AG). The survey was adapted after input from a second ESSB surgeon (RGD), and further refined after pilot testing with four ESSB surgeons. The 46-item electronic survey was distributed between October 2023 and April 2024. To safeguard against duplicate entries, we limited one entry per IP address. The survey involved four sections: 1) demographic data, 2) occupational training, experience and practice, 3) WRMD frequency, symptom severity and frequency and nature of treatment received (participants were asked specifically about work-related symptoms), and 4) ergonomic training and interventions instituted.

Participants

Otorhinolaryngologists and neurosurgeons at any career stage (including trainees) who perform ESSB surgery were contacted and invited to participate via specialist societies. The survey was distributed in English (and in Japanese translated by a native-speaking Japanese rhinologist) by the societies via email.

Outcomes

The primary outcomes were WRMD in the past week and 12 months, consistent with the Nordic Musculoskeletal Questionnaire, a widely used tool with demonstrated reliability and validity designed specifically for occupational use [13]. These defined intervals also restricted the recall period to limit recall bias. Secondary outcomes included the symptom severity, the impact of WRMD on surgeons' work, sleep, activities of daily living, social activities, hobbies and early retirement, and the nature of any treatment received. We determined the proportions who received ergonomic education and/or training, and the nature of any ergonomic interventions implemented. Finally, a post-hoc analysis explored the differences between male and female participants in these secondary outcomes.

Factors associated with WRMD

We evaluated potential risk factors for WRMD, including sex, age,

Table 1. Demographics and associated risk factors for WRMD.

Demographic characteristic	Frequency (n)	%*
Sex: total	1385	100.0
- male	914	66.0
- female	471	34.0
Age (years): total	1385	100.0
- 20 - 25	3	0.2
- 26 – 30	88	6.4
- 31 – 35	230	16.6
- 36 – 40	243	17.6
- 41 – 45	248	17.9
- 46 – 50	172	12.4
- 51 – 55	142	10.3
- 56 – 60	118	8.5
- 61 – 65	81	5.9
- 66 – 70	45	3.3
- 71 – 75	12	0.9
- ≥ 76	3	0.2
Weight (kg/lbs): total	1383	99.9
Female: median (n; IQR)	60.0/132.3 (470; 55.0-69.0)	99.9
Male: median (n; IQR kg)	80.0/176.4 (913; 72.0-87.0)	99.9
BMI (kg/m²):		
Total:	1359	98.1
- <18.5 (underweight)	26	2.0
- 18.5 – 24.9 (normal weight)	732	53.8
- 25.0 – 29.9 (overweight)	492	36.2
- ≥ 30.0 (obese)	109	8.1
Female:		
- total	468	99.4
- <18.5 (underweight)	22	4.7
- 18.5 – 24.9 (normal weight)	334	71.4
- 25.0 – 29.9 (overweight)	85	18.2
- ≥ 30.0 (obese)	27	5.8
Male:		
- total	891	97.5
- <18.5 (underweight)	4	0.4
- 18.5 – 24.9 (normal weight)	398	44.7
- 25.0 – 29.9 (overweight)	408	45.8
- ≥ 30.0 (obese)	81	9.1
Level of practice: total	1385	100
- doctor working in ENT/neurosurgery not on formal training program	111	8.0
- doctor on ENT training program	178	12.9
- doctor on neurosurgery training program	4	0.3
- consultant/attending ENT/ORL surgeon	1047	75.6
- consultant/attending neurosurgeon	25	1.8
- other	20	1.4
Smoking status: total	1385	100.0
- current smoker	61	4.4
- never smoked	1199	86.6
- ex-smoker	125	9.0
Somatotype: total	1314	94.9
- endomorph	412	31.4
- ectomorph	483	36.8
- mesomorph	405	30.8
- ectomorph/mesomorph	9	0.01
- endomorph/mesomorph	2	0.01
Handedness: total	1385	100.0
- right-handed	1271	91.8
- left-handed	68	4.9
- ambidextrous	46	3.3
Fellowship trained in rhinology/anterior skull base surgery: total	1385	100.0
- yes	760	54.9
- no fellowship	472	34.1
- fellowship other than rhinology/anterior skull base	153	11.1

Demographic characteristic	Frequency (n)	%*
Number of ESSBS procedures per year: total	1382	99.8
- <50	503	36.4
- 50-75	308	22.3
- 76-100	193	14.0
- >100	378	27.4
Days per week performing surgery: total	1384	99.9
- 1	323	23.3
- 2	577	41.7
- 3	325	23.5
- 4	94	6.8
- 5	46	3.3
- 6	12	0.9
- 7	7	0.5
Hours per week working in outpatients: total	1382	99.8
- ≤5	87	6.30
- 6-10	254	18.4
- 11-20	435	31.5
- >20	606	43.8
Number of years performing ESSBS: total	1384	99.9
- < 1	51	3.7
- 1 – 5	233	16.8
- 6 – 10	289	20.9
- 11 – 15	286	20.7
- 16 – 20	205	14.8
- 21 – 25	147	10.6
- ≥ 26	173	12.5
Hours of sleep per night: total	1385	100.0
- <5	15	1.1
- 5	100	7.2
- 6	496	35.8
- 7	605	43.7
- 8	162	11.7
- ≥ 9	7	0.5
Exercise/week: total	1337	96.5
- not at all	92	6.9
- ≤1 hour	332	24.8
- >1 – 2 hours	226	16.9
- >2 – 3 hours	219	16.4
- >3 – 4 hours	155	11.6
- >4 – 5 hours	105	7.9
- >5 – 6 hours	75	5.6
- >6 – 7 hours	46	3.4
- > 7 hours	87	6.5
Percentage of practice involving rhinoplasty: total	1383	99.9
- 0%	618	44.7
- 1 – 20%	527	38.1
- 21 – 40%	143	10.3
- 41 – 60%	51	3.7
- 61 – 80%	26	1.9
- ≥ 80%	18	1.3
Perform ESS/ESSBS in sitting, standing or both: total	1382	99.8
- sitting position only	103	7.5
- standing position only	1195	86.5
- sitting and standing position	84	6.1
Perform ESSBS using camera and endoscope or view directly via endoscope: total	1385	100.0
- camera and endoscope viewed on monitor	1325	95.7
- endoscope directly with no camera or monitor	24	1.7
- both	36	2.6
Use monitor on cart, boom, both or other: total	1361	98.3
- portable cart	875	64.3
- ceiling mounted boom	140	10.3
- both	341	25.1
- other	5	0.4

Demographic characteristic	Frequency (n)	%*
Preferred side of patient to sit/stand when operating: total	1383	99.9
- patient's left	86	6.2
- patient's right	1279	92.5
- head of patient	5	0.4
- no preference	13	0.9
Glove size: total	1385	100.0
- < 6	20	1.4
- 6	95	6.9
- 6.5	282	20.4
- 7	302	21.8
- 7.5	459	33.1
- 8	182	13.1
- 8.5	40	2.9
- 9	2	0.1
- 9.5	1	0.1
- ≥10.0	2	0.1
First developed WRMD: total responses	893	97.0
- before specialty training	69	7.7
- during specialty training	288	32.3
- within the 1st year as a consultant/attending surgeon	73	8.2
- >1 - 5 years as a consultant/attending surgeon	178	19.9
- >5 - 10 years as a consultant/attending surgeon	141	15.8
- ≥ 10 years as a consultant/attending surgeon	144	16.1
Treatment for WRMD: total responses (% of those with WRMD)	897	97.4
- yes overall	471	52.5
- yes female (% of those within sex)	194	56.0
- yes male (% of those within sex)	280	50.4
WRMD requiring stop or pause surgery: total responses (% of those with WRMD)	887	96.3
- yes overall	267	30.1
- yes female (% of those within sex)	106	31.4
- yes male (% of those within sex)	161	29.3
WRMD requiring time off work: total responses (% of those with WRMD)	887	96.3
- yes overall	125	14.1
- yes female (% of those within sex)	52	15.4
- yes male (% of those within sex)	73	13.3
Impact of WRMD on hobbies: total responses (% of those with WRMD)	886	96.2
- yes overall	433	48.9
- yes female (% of those within sex)	164	48.7
- yes male (% of those within sex)	269	49.0
Impact of WRMD on ADLs: total responses (% of those with WRMD)	886	96.2
- yes overall	447	50.5
- yes female (% of those within sex)	186	55.2
- yes male (% of those within sex)	261	47.5
Impact of WRMD on sleep: total responses (% of those with WRMD)	886	96.2
- yes overall	465	52.4
- yes female (% of those within sex)	187	55.5
- yes male (% of those within sex)	278	50.6
WRMD shortened career longevity or planned early retirement: total responses (% of those with WRMD)	886	96.2
- yes overall	112	12.6
- yes female (% of those within sex)	40	11.9
- yes male (% of those within sex)	72	13.1

*% are expressed as % of total responses in each category; IQR: interquartile range; WRMD: work-related musculoskeletal disorders.

body habitus, glove size, smoking status, handedness, seniority, experience, fellowship training, case volume, clinic time, surgical set-up, the percentage of practice involved in rhinoplasty, whether the surgery was performed sitting or standing, amount of sleep and exercise.

Statistical analysis

Responses with missing data for a variable being analysed were excluded casewise. Descriptive statistics (means with standard deviations and medians with interquartile range for numerical variables, frequency and percentage for categorical variables) were used to summarise participant characteristics and prevalence data. Certain descriptive statistics were stratified by sex (weight, height, BMI, prevalence of WRMD, glove size, treatment of WRMD, received ergonomics training, ergonomic interventions and impact of WRMD on surgical practice, absenteeism, hobbies, activities of daily living (ADLs), sleep and career longevity) as multiple studies reported a significant difference in WRMD between sexes and we felt that differences in these risk factors between sexes may be partially responsible. Two group comparisons of difference of proportions were used to compare the differences in WRMD in the extremes of glove size and for the institution of ergonomic interventions between sexes. A multivariable logistic regression analysis was used (reported with odds ratio (OR) and 95% confidence intervals (CI)) to analyse factors that may influence or contribute to WRMD. An informed model was utilised, including selected variables, rather than relying on significance of variables from a set of univariable analyses, to avoid potentially rejecting appropriate variables and including inappropriate ones [14]. Non-significant variables that, if removed from the model, changed the estimate/beta values by >10% were taken as an indication of confounding and therefore, remained in the analysis to avoid confounding bias. Two fellowship-trained ESSB surgeons (RGC, RGD) consulted and selected plausibly important variables to include in the multivariable analysis, published literature and their experience. Variance inflation factors (VIF) were calculated to assess for multicollinearity of independent variables. When added, any variable with a VIF ≥5 was considered for removal from the analysis [15]. Data were analysed using the Statistical Package for Social Sciences for Mac (SPSS version 29.0.2.0; IBM SPSS Statistics, IBM Corp, Armonk, NY, USA) and Jamovi version 2.6.44.0 (https://www.jamovi.org, Sydney, Australia).

Results

We received 1614 responses, with 229 incomplete responses in the variables of interest, leaving 1385 responses with data suitable for analysis. The exact response rate could not be calculated as many participants were members of multiple societies and therefore, received the survey more than once. However, approximately 7946 surveys were distributed giving an estimated response rate of 20.3%. In Australia, the response rate was 38.6%.

Participant characteristics

Participants trained across 81 and practised in 87 countries, and the majority were male (66.0%, Table 1). Regarding primary somatotype, 31.4% identified as endomorphic, 36.8% as ectomorphic and 30.8% as mesomorphic. The majority of participants were otolaryngology consultants (75.6%), lifelong non-smokers (86.6%) and were right-handed (91.8%). Over half the participants (54.9%) had completed an ESSB surgery fellowship.
Over one quarter of the cohort (27.4%) performed >100 ESSB surgery procedures/year with most performing surgery 1-3 days/week (88.5%). Standing was the preferred position for operating (86.5%), most used a monitor (95.7%) mounted on a portable cart (64.3%). Very few participants used an endoscope holder (6.8%). There were no female participants with a glove size of ≥8.0, and 4 male participants had a glove size of ≤6. The 5 participants with sizes 9, 9.5 and 10 were combined into one group for analysis. Most participants preferred to position themselves on the patient's right side during surgery (92.3%).

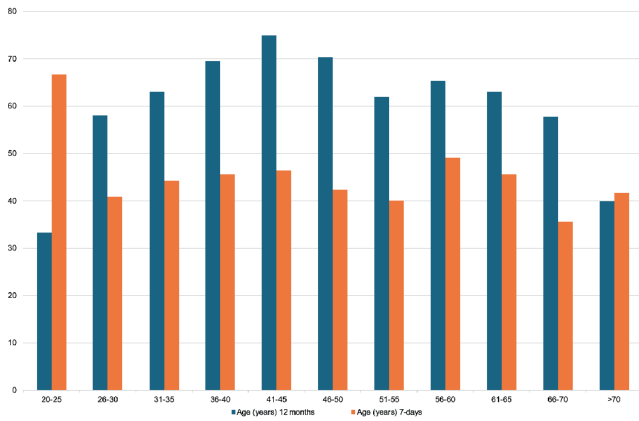

Figure 1. Prevalence of WRMD in the last week and 12 months by age.

Prevalence of work-related musculoskeletal disorders

The overall prevalence of WRMD in the past week and 12-months was 44.2% and 66.5%, respectively (Table 2). Female participants had more WRMD than male participants (week: 51.8% vs 40.3%. 12-months: 75.4% vs 61.9%). In the past week and past 12 months, the 20-25 year and 41-45 year age group, had the most WRMD, respectively (Figure 1). Otolaryngology consultants had the highest prevalence of WRMD (69.3%). The most common time to first develop symptoms was during training (32.3%). Of those with WRMD, 94.6% had multisite symptoms (Appendix 2).

Factors associated with WRMD

On multivariable logistic regression analysis (Table 3), the following variables were associated with higher odds of WRMD in the last week: compared to males, females had 2.4 times higher odds (CI 1.5–3.7; p<0.001), BMI ≥30.0kg/m^2 (reference ≤18.5kg/m^2: OR 5.0; CI 1.7–14.3; p=0.003), performing >100 ESSB surgery cases/year (reference <50 cases/year: OR 1.7; CI 1.2–2.5; p=0.004) and working both 6-10 and >10-20 hours per week in outpatients clinic (reference ≤5 hours/week: for 6-10 hours/week OR 2.0; CI 1.1–3.6; p=0.02). Exercising >7 hours/week (reference no exercise: OR 0.5; CI 0.2-0.9; p=0.03) and endomorphic somatotype (reference ectomorph: OR 0.7; CI 0.5-0.96; p=0.03) were associated with lower odds of WRMD.

Table 2. Work related musculoskeletal disorders (WRMD) in the past week and 12 months.

Variable	Total n	Subgroup	WRMD last 12-months Yes: n (% within each subgroup category)	WRMD last 7-days Yes: n (% within each sub-group category)
Overall prevalence	1385		921 (66.5)	312 (44.2)
Age (years)	1385	20 – 25	1 (33.3)	2 (66.7)
		26 - 30	51 (58.0)	36 (40.9)
		31 - 35	145 (63.0)	102 (44.3)
		36 - 40	169 (69.5)	111 (45.7)
		41 - 45	186 (75.0)	115 (46.4)
		46 - 50	121 (70.3)	73 (42.4)
		51 - 55	88 (62.0)	57 (40.1)
		56 - 60	77 (65.3)	58 (49.2)
		61 - 65	51 (63.0)	37 (45.7)
		66 - 70	26 (57.8)	16 (35.6)
		71 - 75	5 (41.7)	5 (41.7)
		≥ 76	1 (33.3)	0 (0.0)
BMI (kg/m^2)	1360	<18.5 (underweight)	17 (66.7)	11 (44.4)
		18.5 – 24.9 (normal weight)	495 (67.6)	318 (43.4)
		25.0 – 29.9 (overweight)	310 (63.0)	210 (42.7)
		≥ 30.0 (obese)	81 (75.0)	61 (56.5)
Sex	1385	M	566 (62.0)	368 (40.3)
		F	355 (75.4)	244 (51.8)
Handedness	1385	Right	855 (67.3)	566 (44.5)
		Left	38 (55.9)	25 (36.8)
		Ambidextrous	28 (60.9)	21 (45.7)
Somatotype	1314	Ectomorph/mesomorph	7 (77.8)	4 (44.4)
		Endomorph/mesomorph	1 (50.0)	1 (50.0)
		Ectomorph	323 (66.9)	214 (44.3)
		Endomorph	280 (68.0)	186 (45.1)
		Mesomorph	263 (64.8)	178 (43.8)
Level of practice	1385	ORL/ENT/neurosurgical trainee not on program	54 (48.6)	39 (35.1)
		ORL/ENT trainee	110 (61.8)	77 (43.3)
		Neurosurgical trainee	4 (100.0)	3 (75.0)
		ORL/ENT attending	726 (69.3)	472 (45.1)
		Neurosurgical attending	15 (60.0)	10 (40.0)
		Other	12 (60.0)	11 (55.0)
ESSBS fellowship trained	1385	Not fellowship trained	390 (62.4)	251 (40.2)
		Fellowship trained	531 (69.9)	361 (47.5)
Hours of sleep/night	1385	<5	9 (60.0)	9 (60.0)
		5	65 (65.0)	45 (45.0)
		6	343 (69.2)	238 (48.0)
		7	406 (67.1)	256 (42.3)
		8	94 (58.0)	60 (37.0)
		≥9	4 (57.1)	4 (57.1)
ESSBS cases/year	1382	<50	316 (62.8)	201 (40.0)
		50-75	200 (64.9)	136 (44.2)
		76-100	136 (70.5)	93 (48.2)
		>100	267 (70.6)	182 (48.1)
Days operating per week	1385	1	198 (61.3)	130 (40.2)
		2	406 (70.4)	268 (46.4)
		3	214 (65.8)	145 (44.6)
		4	59 (62.8)	40 (42.6)
		5	29 (63.0)	21 (45.7)
		6	11 (91.7)	5 (41.7)
		7	3 (42.9)	3 (42.9)
Glove size	1385	5.5	14 (70.0)	9 (45.0)
		6.0	64 (67.4)	51 (53.7)
		6.5	208 (73.8)	138 (48.9)
		7.0	203 (67.2)	131 (43.4)
		7.5	289 (63.0)	195 (42.5)
		8.0	123 (67.6)	75 (41.2)
		8.5	17 (42.5)	11 (27.5)
		≥9.0	3 (60.0)	2 (40.0)

Variable	Total n	Subgroup	WRMD last 12-months Yes: n (% within each subgroup category)	WRMD last 7-days Yes: n (% within each subgroup category)
Hours per week in outpatients/clinic	1382	≤5	45 (51.7)	29 (33.3)
		6-10	171 (67.3)	112 (44.1)
		11-20	300 (69.0)	195 (44.8)
		>20	403 (66.5)	29 (45.5)
Number of years performing ESSBS	1384	<1	27 (52.9)	21 (41.2)
		1-5	147 (63.1)	94 (40.3)
		6-10	197 (68.2)	137 (47.4)
		11-15	212 (74.1)	129 (45.1)
		16-20	137 (66.8)	82 (40.0)
		21-25	93 (63.3)	73 (49.7)
		≥26	107 (61.8)	76 (43.9)
Smoking status	1385	Non-smoker	881 (66.5)	581 (43.9)
		Smoker	40 (65.6)	31 (50.8)
% practice rhinoplasty	1383	0%	414 (67.0)	278 (45.0)
		1-20%	349 (66.2)	240 (45.5)
		21-40%	91 (63.6)	52 (36.4)
		41-60%	30 (58.8)	22 (43.1)
		61-80%	20 (76.9)	10 (38.5)
		≥81%	16 (88.9)	10 (55.6)
Perform ESSBS sitting or standing	1382	Sitting	53 (51.5)	39 (37.9)
		Standing	808 (67.6)	540 (45.2)
		Both	57 (67.9)	33 (39.3)
ESSBS via monitor or directly via endoscope	1385	Direct via endoscope	10 (41.7)	6 (25.0)
		Both	20 (55.6)	14 (38.9)
		Monitor	891 (67.2)	592 (44.7)
ESSBS monitor on cart or ceiling mounted boom	1385	Other	3 (60.0)	4 (80.0)
		Cart	587 (67.1)	394 (45.0)
		Both	231 (67.7)	144 (42.2)
		Ceiling-mounted boom	90 (64.3)	64 (45.7)
Endoscope holder	1385	Not use endoscope holder	866 (67.1)	575 (44.5)
		Use endoscope holder	55 (58.5)	37 (39.4)
Exercise frequency/week	1337	Not at all	68 (73.9)	44 (47.8)
		≤1 hour	236 (71.1)	173 (52.1)
		>1 – 2 hours	134 (68.1)	105 (46.5)
		>2 – 3 hours	154 (63.9)	78 (35.6)
		>3 – 4 hours	140 (60.6)	60 (38.7)
		>4 – 5 hours	94 (62.9)	46 (43.8)
		>5 – 6 hours	66 (69.3)	34 (45.3)
		>6 – 7 hours	52 (63.0)	20 (43.5)
		>7 hours	40 (46.0)	26 (29.9)
Ergonomics training	1339	No training (% within those not receiving training)	736 (64.3)	478 (41.7)
		Training (% within those receiving training)	145 (74.7)	110 (56.7)
Instituted ergonomic interventions	1338	Not instituted interventions (% within those who had not instituted interventions)	630 (62.6)	417 (41.5)
		Instituted interventions (% within those who had instituted interventions)	250 (75.3)	170 (51.2)

ESSBS: endoscopic sinus and skull base surgery.

The following variables were associated with higher odds of WRMD in the last 12 months: compared to males, females had 2.9 times higher odds (CI 1.8–4.7; p<0.001), BMI ≥30.0kg/m^2 (reference ≤18.5kg/m^2: OR 3.9; CI 1.3-12.0; p=0.02), being an otolaryngology consultant (reference otolaryngology trainee not on a formal training program: OR 2.4; CI 1.5-3.9; p<0.001), performing >100 ESSB surgery cases/year (reference <50 cases/year OR 1.5; CI 1.0–2.2; p=0.04), spending 6-10 hrs in outpatients clinic/week (reference ≤5 hours/week, OR 2.0; CI 1.1–3.6; p=0.02), and operating in standing (reference sitting: OR 1.6; CI 1.0–2.6; p=0.04). Exercising >7hrs/week was associated with lower odds of WRMD (reference no exercise: OR 0.3; CI 0.1–0.6; p<0.001).

A subgroup analysis of the extremes of glove size (≤6.0 and ≥8.5) noted that those with a glove size of ≤6.0 (n=115) had the highest prevalence of WRMD while those with a glove size of ≥8.5 (n=45) had the lowest prevalence (7-day prevalence 52.2% vs 28.9% respectively; CI 6%-38%; p=0.008. 12-month prevalence 67.8% vs 44.4%; CI 6%-39%; p=0.006).

Table 3. Factors associated with WRMD in the last 7-days and 12-months based on the multivariable logistic regression analysis.

	WRMD in last 12 months		WRMD in last 7 days	
Variable	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Age	0.9 (0.8 – 1.1)	0.3	0.9 (0.8 – 1.1)	0.3
Height	1.0 (0.98 – 1.03)	0.6	1.0 (1.0 - 1.01)	0.5
Sex (male reference variable)				
- female	2.9 (1.8 – 4.7)	**<0.001**	2.4 (1.5 – 3.7)	**<0.001**
BMI				
- <18.5*				
- 18.51 – 25.9	2.1 (0.8 – 5.2)	0.1	2.0 (0.8 – 5.0)	0.1
- 25.0 – 29.9	1.8 (0.7 – 4.7)	0.2	2.5 (1.0 – 6.5)	0.06
- ≥30.0	3.9 (1.3 – 12.0)	**0.02**	5.0 (1.7 – 14.3)	**0.003**
Somatotype				
- ectomorph*				
- endomorph	0.9 (0.6 – 1.2)	0.4	0.7 (0.5 – 1.0)	**0.03**
- mesomorph	1.0 (0.7 – 1.4)	1.0	0.9 (0.7 – 1.3)	0.6
- ectomorph-mesomorph	1.6 (0.3 – 8.7)	0.6	0.7 (0.1 – 3.1)	0.6
- endomorph-mesomorph	0.8 (0.04 – 15.9)	0.9	2.2 (0.1 – 39.5)	0.6
Level of practice				
- doctor working in ENT/ORL or neurosurgery, not on a formal training program*				
- doctor on ENT/ORL training program	1.5 (0.9 – 2.6)	0.1	1.4 (0.8 – 2.4)	0.3
- doctor on neurosurgical training program	N/A		5.0 (0.4 – 57.6)	0.2
- consultant/attending ENT/ORL surgeon	2.4 (1.5 – 3.9)	**<0.001**	1.5 (0.9 – 2.4)	0.1
- consultant neurosurgeon	1.7 (0.6 – 4.8)	0.3	1.3 (0.5 – 3.9)	0.6
- other	2.7 (0.8 – 9.1)	0.1	1.9 (0.6 – 6.2)	0.3
Number of ESSBS cases/yr				
- <50*				
- 50 – 75	1.0 (0.7 – 1.5)	0.8	1.5 (1.1 – 2.1)	**0.02**
- 76 – 100	1.4 (0.9 – 2.1)	0.1	1.7 (1.1 – 2.5)	**0.02**
- >100	1.5 (1.01 – 2.2)	**0.04**	1.7 (1.2 – 2.5)	**0.004**
Glove size				
- 5.5*				
- 6.0	0.6 (0.2 – 2.3)	0.5	1.7 (0.5 – 5.8)	0.4
- 6.5	1.0 (0.3 – 3.4)	1.0	1.6 (0.5 – 5.1)	0.4
- 7.0	1.3 (0.4 – 4.5)	0.8	1.7 (0.5 – 5.9)	0.4
- 7.5	1.3 (0.4 – 5.0)	0.7	2.5 (0.7 – 8.8)	0.2
- 8.0	1.7 (0.4 – 7.0)	0.4	2.2 (0.6 – 8.3)	0.3
- 8.5	0.5 (0.1 – 2.2)	0.3	1.0 (0.2 – 4.5)	1.0
- ≥ 9.0	3.3 (0.2 – 51.1)	0.4	3.9 (0.3 – 44.2)	0.3
Days per week performing surgery	1.1 (0.9 – 1.2)	0.3	1.1 (0.9 – 1.2)	0.3
Hours per week in outpatients				
- ≤ 5*				
- 6-10	2.0 (1.1 – 3.6)	**0.02**	2.0 (1.1 – 3.6)	**0.02**
- 11-20	1.9 (1.1 – 3.2)	**0.02**	1.7 (1.0 – 3.1)	0.05
- > 20	1.7 (0.99 – 2.8)	0.054	1.7 (1.0 – 2.9)	0.06
Number of yrs performing ESSBS				
- < 1*				
- 1 – 5	0.8 (0.4 – 1.6)	0.5	0.6 (0.3 – 1.2)	0.2
- 6 – 10	0.8 (0.4 – 1.8)	0.6	0.7 (0.3 – 1.5)	0.4
- 11 – 15	1.1 (0.5 – 2.5)	0.8	0.7 (0.3 – 1.6)	0.4
- 16 – 20	0.8 (0.3 – 1.9)	0.6	0.6 (0.3 – 1.4)	0.2
- 21 – 25	0.8 (0.3 – 2.1)	0.7	1.0 (0.4 – 2.6)	0.9
- ≥ 26	1.1 (0.4 – 3.1)	0.9	1.1 (0.4 – 3.1)	0.8
Perform ESSBS in sitting or standing				
- Sitting*				
- Standing	1.6 (1.02 – 2.6)	**0.04**	1.3 (0.8 – 2.0)	0.4
- Both	1.6 (0.8 – 3.1)	0.2	1.0 (0.5 – 1.9)	0.9

	WRMD in last 12 months		WRMD in last 7 days	
Variable	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Exercise frequency/week				
- nil*				
- < 1hr	0.9 (0.5 – 1.7)	0.8	1.2 (0.7 – 2.0)	0.5
- 1 - 2hr	0.9 (0.5 – 1.6)	0.6	1.1 (0.6 – 1.8)	0.8
- > 2 – 3 hr	0.7 (0.4 – 1.3)	0.2	0.6 (0.4 – 1.1)	0.1
- >3 – 4hr	0.6 (0.3 – 1.1)	0.1	0.7 (0.4 – 1.2)	0.2
- >4 – 5 hr	0.7 (0.4 – 1.5)	0.4	1.0 (0.5 – 1.8)	0.9
- >5 – 6 hr	0.8 (0.4 – 1.7)	0.6	0.8 (0.4 – 1.6)	0.6
- >6 – 7hr	0.7 (0.3 – 1.8)	0.5	0.8 (0.4 – 1.9)	0.7
- >7hr	0.3 (0.1 – 0.6)	**<0.001**	0.5 (0.2 – 0.9)	**0.03**
Hours of sleep per night				
- 4*				
- 5	1.0 (0.3 – 3.7)	0.9	0.5 (0.1 – 1.6)	0.2
- 6	1.5 (0.5 – 4.9)	0.5	0.7 (0.2 – 2.1)	0.5
- 7	1.4 (0.4 – 4.6)	0.6	0.6 (0.2 – 2.0)	0.4
- 8	0.9 (0.3 – 3.2)	0.9	0.4 (0.1 – 1.5)	0.2
- ≥9	0.7 (0.1 – 6.0)	0.8	1.2 (0.1 – 10.4)	0.8
Fellowship trained in ESSBS				
- no*				
- yes	1.2 (0.9 – 1.5)	0.3	1.2 (0.9 – 1.5)	0.3

BMI: body mass index; CI: confidence interval; OR: odds ratio; WRMD: work related musculoskeletal disorder. *Reference category.

Nature and location of WRMD

The neck was the most commonly affected body region, then the shoulders and lumbar spine (Table 4). These regions also had the highest symptom intensity scores (Appendix 3). Female participants reported higher symptom intensity scores for most body parts. Of those with WRMD, 6.5% stated that the duration of their WRMD was longer than 5 years.

Treatment for WRMD

Approximately half of those with WRMD sought treatment (52.5%) and 27.7% received a formal diagnosis. The most common treatment was physiotherapy (74.3%), medications (58.6%), and complementary therapies (38.2%). Of those who sought treatment, 7.2% underwent surgery. Surgeries included spinal surgery (discectomy, laminectomy, spinal fusion), tendon repairs/releases, joint replacements, and corticosteroid injections.

Impact of WRMD

Due to WRMD, 19.3% of all participants paused surgery, while 18.3% altered their surgical practice. Eight participants (2.9%) who paused surgery did so for hours or abandoned a procedure, and 14.1% took time off work. Work-related musculoskeletal disorders interfered with hobbies (48.9%), sleep (52.5%) and ADLs (50.5%). Nearly 13% of participants (12.6%) stated that WRMD shortened their career longevity or led them to plan to retire earlier. The impact of WRMD on ADLs was significantly greater for female participants (55.2% vs 47.5%; p=0.03). Otherwise, the impact of WRMD was similar between male and female participants.

Ergonomics education, training and interventions

A total of 14.5% of participants had received ergonomics training, and 24.8% had implemented ergonomic interventions. A similar percentage of male and female surgeons received ergonomics training; however, significantly lower proportion of female participants instituted ergonomic interventions (female: 21.4% vs male: 26.5%; CI 0.003-0.12; p=0.04).

Discussion

This is the largest international survey published on WRMDs in ESSBs to date. Our study found that 44.2% of ESSB surgeons have experienced WRMD in the last week and 66.5% in the last year. Most of those with WRMD had symptoms in multiple sites, which is associated with a greater reduction in overall health, sleep quality, work ability and an increased risk of future work disability [16, 17]. Factors significantly associated with an increased risk of WRMD include female sex, a BMI ≥30kg/m^2, being a consultant otolaryngologist, surgical case volume, time spent in the clinic, and operating in standing. Exercising >7 hours/week is associated with lower odds of WRMD, and an endomorphic somatotype is associated with lower odds in the last week. Our study also found that WRMD negatively impacts the daily lives of ESSB surgeons and can lead to early retirement. Previous surveys on ESSB surgeons only reported lifetime prevalence of WRMD (43.4–84.8%) [5], therefore, a comparison between our results and those of other studies is difficult. Regardless, the prevalence of WRMD in ESSB surgeons is high, particularly compared to the general population [18, 19]. For example, 44.8% and 31.4% of our respondents reported neck and lower back pain in the past 12 months compared to 2.6% and 7.4% of the global

Table 4. Heatmap of prevalence of WRMD by body part.

Body part	Left			Right		
	% of total Overall	% of total sex Female	% of total sex Male	% of total Overall	% of total sex Female	% of total sex Male
Head/face	4.6	5.5	4.1	13	17.4	10.7
Neck	43.6	48	41.5	44.8	42.9	40.81
Shoulder	34.9	42.9	30.9	34.5	42.7	52.2
Upper arm	15.9	21.9	12.9	15.7	20.2	13.6
Elbow	11.3	13.8	10.4	11.8	15.1	10.5
Forearm	11.8	14.4	10.6	12.5	16.8	10.3
Wrist	17.1	21.9	14.8	16.3	22.3	13.4
Hand	15.5	19.5	14.9	16.2	19.8	14.6
Fingers	15.3	18.7	13.8	15.3	17.6	14.2
Thumb	13	16.1	11.7	13.5	16.4	12.1
Thoracic spine/chest	15.7	20.6	13.6	15.7	20.2	13.6
Lumbosacral spine	31.4	35	29.7	31.1	35	29.2
Hip	12.2	15.5	10.6	12.5	14.9	11.4
Thigh/upper leg	10.7	13.8	9.2	10.7	13.2	9.5
Knee	14.9	17	14.1	16.5	19.5	15
Lower leg	12.5	16.6	10.5	12.6	15.7	11.2
Ankle	9.7	13	8.4	9.8	12.7	8.5
Foot	13.3	17.6	11.3	13.9	17	12.6
Toes	8.3	11.3	7.8	8.3	10.6	7.4

0-<5	5-<10	10-<15	15-<20	20-<25	25-<30	30-<35	35-<40	40-<45	45-<50	50-<55

population respectively [18, 19]. This prevalence is consistent with other surgical subspecialties [20-23], and is likely to be higher due to under-reporting [4, 22, 23].

High-risk body areas

The areas most impacted by WRMD in surgeons are the neck, shoulders and lower back [5, 24-26]. Previous research suggests the use of an endoscope holder resulted in a significant reduction in EMG activity in the biceps, triceps, deltoid, erector spinae and external oblique muscles during laparoscopic surgery [27], suggesting a potential intervention to reduce WRMD in this population. Devices that aid or support the surgeon were used rarely by the respondents in this survey, and the development and adoption of such aids may be part of the solution.

Sex and WRMD

Our finding that female participants had a significantly higher prevalence of WRMD is consistent with the literature [28]. Female participants also reported higher symptom intensity scores in most areas. One explanation may be the smaller stature and hand size of female participants and the greater relative weight and size of instruments. No female participant had a glove size >7.5. Managing one-size-fits-all equipment has been identified as a major ergonomic challenge for female surgeons [21, 29, 30].

In addition to the relatively heavy camera typically held in the more static left upper limb, the higher left lower limb symptom scores in female participants may also be due to inadequate bed height and the asymmetric stance resulting from foot pedals [29]. Another explanation may be based on sex hormones. Connective tissue cells express sex hormones and different hormone profiles may be associated with musculoskeletal pain and osteoarthritis [31]. Finally, female participants instituted less ergonomic interventions. This may be because female surgeons perceive the effort required to optimise the operating room set-up as time-consuming, and an additional burden that negatively impacts relations with operating room staff and their sense of belonging [29].

Exercise

Exercising >7 hours/week was associated with lower odds of WRMD. This finding is consistent with the literature [26, 32, 33]. It is possible that those who exercise less do so due to their WRMD. However, exercise has medicinal value and is a modifiable risk factor for surgeons. Exercise in surgeons has been shown to improve general health, QoL, and efficiency, and to reduce errors, depression and musculoskeletal discomfort [34-36].

Unfortunately, surgeons often struggle to meet recommended

Table 5. Recommendations.

Category	Subjects	Recommendations
Instrumentation and equipment	Industry	Move away from one-size-fits-all equipment and instruments to develop more modular, adjustable or modifiable equipment and tools with a variety of sizes to accommodate the varying anthropometry in the population using this equipment. Involve surgeons in the design and development of new instruments and equipment.
	Surgeons, hospital administrators	Focus on ergonomics in the clinic as well as in the operating room. For example, providing modular furniture and height adjustable chairs with armrests and height adjustable computer stations. Use of an armrest reduces discomfort, muscle load and error rates in surgery. When sitting, a chair with arm supports reduces neck and shoulder strain and lumbar spine compressive forces. When standing during surgery, theatre staff should use anti-fatigue mats, wear low durometer sport shoes and compression socks/stockings.
Positioning	Hospital administrators	Provide anti-reflective monitors on ceiling-mounted booms to reduce glare and to allow surgeons to adjust the height and position of the monitor. Consider purchasing endoscope holders to reduce the static, loaded posture required to hold an endoscope during ESSBS
	Education and training	Consider alternating sitting and standing for cases. Position the monitor directly in front of the surgeon (no more than 15° to either side in the horizonal plane), 15-35° below the horizontal plane (to reduce the opening of the palpebral fissure and, therefore, corneal exposure and tear film evaporation), angled slightly towards the ceiling at a distance of 140-305cm (57 – 121 in) from the surgeon (depending on screen size, resolution and the surgeon's visual acuity) reduces visual fatigue and improves durability of visual concentration.
Organizational	Surgeons, surgical educators	Providing ergonomics education and training at all stages of a surgeon's career, starting in medical school. Involve hospital management and administration in ergonomics education. Address all 3 elements of surgical ergonomics training: physical, cognitive/psychosocial and organizational.
	Hospital administrators	Providing trained professionals for occupational ergonomic assessments for surgeons. Encourage regular breaks where the surgical team can eat or stretch together to promote team-building. Involve the surgical team in decision making and encourage early identification of ergonomic issues. Ensure clear communication and support from management. Involve surgical staff in brainstorming potential ergonomic improvements.
General Health	Surgeons	Incorporate active stretching microbreaks as an integral part of the day. Consider regular exercise which includes aerobic and resistance/strength training exercise.
	Hospital administrators	Improving access to exercise facilities for surgeons (e.g. providing gyms at hospitals with trained staff and 24-hour access on site) or negotiating for staff discounts at gyms within close proximity to hospitals. These gyms should offer work-based programs including pilates and/or yoga.
Cognitive	Hospital administrators	Foster a no blame culture, rather one of collegiality and support where workers can express themselves freely without risk of ostracism or fear of punishment.
	Surgeons	Mentoring surgical trainees to instil a culture of importance regarding ergonomics, moving away from the self-sacrificing sentiment regarding WRMD in surgery.

exercise guidelines [37, 38]. However, health benefits from exercise occur even if the recommended amount of exercise is compacted into two days [39]. Stretching during lunch breaks reduces musculoskeletal pain and fatigue in healthcare workers [40]. These options may enable surgeons to increase their exercise despite the irregular and long work hours inherent in this profession.

Surgical caseload and time in the outpatient/clinic

The odds of WRMD were significantly higher with a greater surgical caseload and longer time spent in the clinic. It may not be realistic to recommend that surgeons restrict their surgical or clinical caseload. Therefore, it is imperative that the surgical and clinical environment be optimised to reduce ergonomic risk, especially with the increasing popularity of in-office procedures (see recommendations below).

Standing

Most ESSB surgeons stand to operate, which was associated with greater odds of WRMD. We provide recommendations regarding standing in Table 5.

Impact of WRMD

We noted a negative impact of WRMD on the practice of surgery and surgeons' hobbies, ADLs, sleep and career longevity. Work-related musculoskeletal symptoms are associated with higher rates of burnout and lower professional satisfaction [3, 41]. In fact, otolaryngology trainees have some of the highest rates of burnout of all surgical subspecialties [42]. This highlights the three elements of surgical ergonomics: physical, cognitive/psychosocial and organizational. Strategies to address WRMD should not solely focus on the physical elements but should also incorporate improving work relationships, job control/security, work schedules, workflow and effort/reward balance (Table 5) [43].

Ergonomics training and education

Ergonomics training reduces WRMD and ergonomic risk, particularly when training addresses all three elements [43, 44]. Therefore, ergonomic education and training should also involve hospital management and administration to ensure all elements, including psychosocial factors, are addressed (Table 5).

Limitations

Since this is a cross-sectional study, we cannot infer causal relationships between our factors of interest and WRMD. As some participants will perform other types of surgery in addition to ESSB surgery, this is a potential confounder. Despite a high number of responses, we received limited input from neurosurgeons and neurosurgical trainees (2.1% of respondents). Therefore, these results may not be representative of this population. As many respondents were members of more than one society, our response rate and prevalence of WRMD is likely to be an underestimate. This is supported by comparing our findings to a systematic review of WRMD in ESSB surgeons noting a 12-month prevalence of 82% (compared to our prevalence of 66.5%) [5]. We therefore could not accurately evaluate whether this survey is a representative sample of ESSB surgeons, or comment on sampling bias. However, the proportion of women in our survey was similar to that in other published surveys of WRMD in otolaryngologists and of the current makeup of ORL societies, reducing the likelihood of bias due to sex [5, 45]. There is also an inherent possibility of selection bias, as those with WRMD and/or more severe symptoms may have been more likely to respond, thereby overstating the prevalence of WRMD. This survey relied on self-reporting of WRMD and on recall of the timing of onset and duration of WRMD. However, as responses were anonymous and we asked about WRMD in the past week and 12 months, it is unlikely that self-reporting or recall bias would contribute to substantial inaccuracies. Due to an error in REDCap, we could not collect data on the nature of WRMD experienced. However, based on published literature, ORL surgeons commonly report fatigue, pain, stiffness and paraesthesia respectively as their most common WRMD symptoms [5, 46]. It has been hypothesised that endomorphs have a higher source of energy in carbohydrates and lipids that aids in long-term repetitive and intense exercise [47]. However, somatotype was based on self-report and is subjective. Therefore, the finding that endomorphic somatotypes had less WRMD in the last week should be interpreted with caution. Further, the subgroup analysis of extremes of glove size was limited to a smaller subset of our study sample so may not be adequately powered.

Finally, this survey focused on the physical risk factors associated with WRMD. It is well known that risks for WRMD also include cognitive, psychosocial and organizational factors [48].

Future directions/recommendations

Studies evaluating the impact of personalised equipment on WRMD in ESSB surgeons would be beneficial. Currently, females comprise 25% of members of the American Rhinologic Society [49]. Adopting infrastructure, tools and equipment that adapt to the varied anthropometry in our profession would contribute towards a more equitable and inclusive work environment. Most ergonomic studies focus on the operating room; however, we noted that time spent in the clinic was associated with WRMD. Therefore, studies evaluating the unique risk factors posed in the clinic are imperative. While we have discussed our statistically significant findings, the clinical significance of these factors was evaluated and found to be significant.

Based on the existing literature and our findings, we propose recommendations regarding WRMD in ESSB surgeons in Table 5.

Conclusion

Endoscopic sinus and skull base surgeons have a high prevalence of WRMD which negatively impact surgeons' performance and QoL and can shorten careers. The long-term implications include higher attrition rates and restricted patient access to surgical approaches (to those less painful for the surgeon). Ergonomic interventions may be effective in reducing WRMD, which is imperative in the current climate of healthcare workforce shortages. Many interventions will require trials and significant financial and temporal investment. However, there are simple and effective strategies available that can be implemented immediately. Finally, more detailed assessments of the organizational, psychosocial and cognitive factors associated with WRMD in ESSB surgeons are required for a more holistic approach to this problem.

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Author contributions

RGC: conception and survey design; literature review, data acquisition, analysis and interpretation; drafting of the manuscript; revision; final approval; agreement to be accountable.

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Conflict of interest

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SUPPLEMENTARY MATERIAL

Appendix 1. Survey questions.

1. What is your age in years?
2. What is your weight?
3. What is your height?
4. Please select your body type:
   a. Ectomorph: lean, tall build with minimal adipose tissue
   b. Endomorph: rounder shape with more adipose tissue
   c. Mesomorph: muscular build
5. What is your sex?
   a. Male
   b. Female
   c. Other
6. Are you left or right-handed?
   a. Right-handed
   b. Left-handed
   c. Ambidextrous
7. In which country did you undertake your specialist surgical training?
8. In which country do you currently primarily practice?
9. What is your level of practice?
   a. Doctor working in ENT/ORL or neurosurgery but not on a formal training program
   b. Doctor on formal ENT/ORL training program
   c. Doctor on formal neurosurgical training program
   d. Consultant/attending ENT/ORL surgeon
   e. Consultant/attending neurosurgeon
   f. Other
10. Are you fellowship trained in rhinology and/or anterior skull base surgery?
11. Have you completed a fellowship in another specialty?
12. How many hours of sleep per night do you get?
13. What is your smoking status
    a. Current smoker
    b. Current non-smoker
14. How many endoscopic sinus and/or skull base procedures do you perform per year?
    a. <50
    b. 50 – 75
    c. 76 – 100
15. How many days per week do you perform surgery?
16. How many hours per week do you work in an outpatient setting?
    a. ≤ 5
    b. 6-10
    c. 11-20
    d. > 20
17. For how many years have you been performing endoscopic sinus and/or skull base surgery?
    a. < 1
    b. 1 – 5
    c. 6 – 10
    d. 11 – 15
    e. 16 – 20
    f. 21 – 25
    g. ≥ 26
18. What percentage, if any, of your annual practice involves rhinoplasty?
    a. 0
    b. 1-20%
    c. 21-40%
    d. 41-60%
    e. 61-80%
    f. ≥81%
19. Do you perform endoscopic sinus and/or skull base surgery in the sitting or standing position?
    a. Sitting
    b. Standing
    c. Both
20. On which side of the patient do you prefer to sit or stand when you operate?
    a. Patient's left
    b. Patient's right
    c. Head of patient
    d. No preference
21. On which side of the patient's sinuses do you find it more comfortable to operate?
    a. Left sinuses
    b. Right sinuses
    c. No preference
22. What is your glove size?
23. Do you perform endoscopic sinus and/or skull base surgery via a camera and endoscope (viewed on a monitor) or viewed directly via an endoscope (without use of a camera and monitor)?
    a. Direct via endoscope
    b. Both
    c. Via a monitor
24. Do you use a monitor mounted on a portable cart or on a ceiling mounted boom?
    a. Cart
    b. Ceiling mounted boom
    c. both
25. Do you use an endoscope holder?
26. In the last 7-days have you had any work-related musculoskeletal symptoms

27. In the last 12-months have you had any work-related musculoskeletal symptoms
28. Please enter a score from 1 (mild symptoms) to 10 (severe symptoms) in the body parts affected by your work-related musculoskeletal symptoms in the last 12-months.

Region	left	Right
Head/face		
Neck		
Shoulder		
Upper arm		
Elbow		
Forearm		
Wrist		
Hand		
Fingers		
Thumb		
Thoracic spine/chest		
Lumbosacral spine		
Hip		
Thigh/upper leg		
Knee		
Lower leg		
Ankle		
Foot		
Toes		

29. When did you first develop your work-related musculoskeletal symptoms?
    a. Before specialty training
    b. During specialty training
    c. Within the first year as a consultant/attending surgeon
    d. >1-5 years as a consultant/attending surgeon
    e. >5-10 years as a consultant/attending surgeon
    f. >10 years as a consultant/attending surgeon
30. What is the shortest duration of your worst or predominant work-related musculoskeletal symptom/s?
    a. <6weeks
    b. 6 weeks - <3 months
    c. 3 months - <6 months
    d. 6 months - <12 months
    e. 1 – <2 years
    f. 2 - <3 years
    g. 3 - <5 years
    h. ≥5 years
31. What is the longest duration of your worst or predominant work-related musculoskeletal symptom/s?
    a. <6weeks
    b. 6 weeks - <3 months
    c. 3 months - <6 months
    d. 6 months - <12 months
    e. 1 – <2 years
    f. 2 - <3 years
    g. 3 - <5 years
    h. ≥5 years
32. Have you had any treatment for your work-related musculoskeletal symptom/s?
33. If you have had treatment, what type of treatment have you had?
    a. Medication
    b. Physiotherapy
    c. Chiropractic
    d. Medical (e.g. general practitioner, non-GP specialist etc)
    e. Surgical
    f. Complementary (e.g. acupuncture, massage)
    g. Other
34. Have you ever had to stop or pause surgery due to your work-related musculoskeletal symptoms?
35. If you have had to stop or pause surgery, how long did you have to stop or pause surgery for?
    a. Seconds
    b. Minutes
    c. Hours
    d. Abandon procedure
36. Have you ever had to take time off work due to your work-related musculoskeletal symptoms?
37. If you have taken time off, what was the duration of your time off work for your work-related musculoskeletal symptoms?
38. Have your work-related musculoskeletal symptoms ever interfered with your hobbies?
39. Have your work-related musculoskeletal symptoms ever interfered with your activities of daily living?
40. Have your work-related musculoskeletal symptoms ever interfered with your sleep?
41. Have you ever received a diagnosis for your work-related musculoskeletal symptoms?
    a. Please detail
42. Have you altered your surgical practice due to your work-related musculoskeletal symptoms?
43. Have your work-related musculoskeletal symptoms shortened your career longevity, or do you plan to cease working earlier due to your work-related musculoskeletal symptoms?
44. How often do you exercise?
    a. Not at all
    b. ≤1 hour/week
    c. >1 – 2 hours/week
    d. >2 – 3 hours/week
    e. >3 – 4 hours/week
    f. >4 – 5 hours/week
    g. >5 – 6 hours/week

h. >6 – 7 hours/week
i. >7 hours/week

45. Have you ever received any ergonomics training?
46. Have you ever implemented any ergonomics interventions into your practice?
a. Please detail

Appendix 2. Number of WRMD sites.

Number of WRMD body sites	Total n (% of population)	Female n (% within sex)	Male n (% within sex)
0	482 (34.8)	128 (27.2)	354 (38.8)
1	49 (3.5)	16 (3.4)	33 (3.6)
2 - 5	404 (29.2)	129 (27.4)	275 (30.1)
6 - 10	232 (16.8)	103 (21.9)	129 (14.1)
11 - 15	61 (4.4)	24 (5.1)	37 (4.1)
16 - 20	30 (2.2)	16 (3.4)	14 (1.5)
21 - 25	17 (1.2)	10 (2.1)	7 (0.8)
26 - 30	10 (0.7)	6 (1.3)	4 (0.4)
31 - 35	5 (0.4)	3 (0.6)	2 (0.2)
36 - 38	94 (6.8)	36 (7.6)	58 (6.4)
Total population	1384	471	913

WRMD: work-related musculoskeletal disorders

Appendix 3. Symptom scores for those with WRMD (scale 0-10).

	Left			Right		
Body part	Overall Median (IQR)	Female Median (IQR)	Male Median (IQR)	Overall Median (IQR)	Female Median (IQR)	Male Median (IQR)
Head/face	1.0 (0.75-3.0)	1.0 (1.0-4.0)	1.0 (0.0-2.0)	1.0 (0.0-3.0)	1.5 (0.0-4.0)	1.0 (0.0-2.0)
Neck	5.0 (3.0-6.0)	5.0 (3.0-7.0)	4.0 (3.0-5.0)	5.0 (3.0-6.0)	5.0 (3.0-6.0)	4.0 (3.0-6.0)
Shoulder	4.0 (2.0-6.0)	5.0 (3.0-6.25)	4.0 (2.0-5.0)	4.0 (2.0-6.0)	5.0 (3.0-7.0)	4.0 (2.0-5.0)
Upper arm	2.0 (1.0-5.0)	3.0 (1.0-5.0)	1.0 (0-3.0)	2.0 (1.0-5.0)	3.0 (1.0-5.0)	1.0 (0.75-3.0)
Elbow	1.0 (0-2.0)	1.0 (0-2.0)	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (0-4.0)	1.0 (0-3.0)
Forearm	1.0 (0-2.0)	1.0 (0-2.0)	1.0 (0-2.0)	1.0 (0-3.0)	1.0 (0-4.0)	1.0 (0-3.0)
Wrist	2.0 (1.0-4.0)	3.0 (1.0-5.0)	2.0 (1.0-3.0)	2.0 (1.0-4.0)	2.0 (1.0-5.0)	2.0 (0.5-4.0)
Hand	2.0 (1.0-4.0)	2.0 (1.0-5.0)	2.0 (1.0-3.0)	2.0 (1.0-4.5)	2.0 (1.0-5.0)	2.0 (1.0-4.0)
Fingers	1.0 (0-4.0)	2.0 (0-4.0)	1.0 (1.0-3.0)	1.0 (0-4.0)	1.0 (0-4.0)	1.0 (0-4.0)
Thumb	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (1.0-4.0)	1.0 (0-3.0)
Thoracic spine/chest	2.0 (0-4.0)	2.0 (0-5.0)	2.0 (0-4.0)	2.0 (1.0-5.0)	2.0 (0-5.0)	2.0 (1.0-5.0)
Lumbosacral spine	4.0 (2.0-6.0)	4.0 (2.0-6.0)	4.0 (2.0-6.0)	5.0 (2.0-6.0)	4.0 (2.0-6.0)	5.0 (3.0-7.0)
Hip	1.0 (0-4.0)	1.0 (0-5.0)	1.0 (0-3.0)	1.0 (0-4.0)	1.0 (0-4.0)	1.0 (0-4.0)
Thigh/upper leg	1.0 (1-3.0)	1.0 (0-3.0)	1.0 (0-2.0)	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (0-2.0)
Knee	1.0 (0-4.0)	1.0 (0-3.25)	1.0 (1.0-4.0)	2.0 (0.75-4.0)	2.0 (0-4.0)	2.0 (1.0-5.0)
Lower leg	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (0-3.0)	1.0 (0-3.0)
Ankle	1.0 (0-2.0)	1.0 (0-2.25)	1.0 (0-2.0)	1.0 (0-2.0)	1.0 (0-2.0)	1.0 (0-2.0)
Foot	1.0 (0-4.0)	2.0 (0-4.25)	1.0 (0-3.0)	1.0 (0-4.0)	2.0 (0-5.0)	1.0 (0-3.0)
Toes	1.0 (0-1.0)	1.0 (0-1.0)	1.0 (0-1.0)	1.0 (0-1.0)	1.0 (0-2.0)	1.0 (0-1.0)