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Prevalence of Work-Related Musculoskeletal Disorders Among Surgeons and Interventionalists
A Systematic Review and Meta-analysis

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IMPORTANCE Physicians in procedural specialties are at high risk for work-related musculoskeletal disorders (MSDs). This has been called "an impending epidemic" in the context of the looming workforce shortage; however, prevalence estimates vary by study.

OBJECTIVES To estimate the prevalence of work-related MSDs among at-risk physicians and to evaluate the scope of preventive efforts.

DATA SOURCES AND STUDY SELECTION Systematic search in MEDLINE (Ovid), Embase (Elsevier), Web of Science, PubMed (National Center for Biotechnology Information), and 2 clinical trial registries, without language restriction, for studies reporting on the prevalence and prevention of work-related MSDs among at-risk physicians published until December 2016. The Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines for meta-analyses and systematic reviews of observational studies were used. At-risk physicians were defined as surgeons and medical interventionalists. Studies reporting on specific disorders or pain assessed with validated instruments were included.

DATA EXTRACTION AND SYNTHESIS Study characteristics; disease prevalence for the neck, shoulder, back, and upper extremity; and measures of resulting disability were recorded. Study estimates were pooled using random-effects meta-analytic models.

MAIN OUTCOMES AND MEASURES Career prevalence of injuries and 12-month prevalence of pain.

RESULTS Among 21 articles (5828 physicians [mean age, 46.0 years; 78.5% male; 12.8 years in practice; 14.4 hours performing procedures per week]) included in this systematic review and meta-analysis, pooled crude prevalence estimates of the most common work-related MSDs were degenerative cervical spine disease in 17% (457 of 2406 physicians) (95% CI, 12%-25%), rotator cuff pathology in 18% (300 of 1513 physicians) (95% CI, 13%-25%), degenerative lumbar spine disease in 19% (544 of 2449 physicians) (95% CI, 5%-16%), and carpal tunnel syndrome in 9% (256 of 2449 physicians) (95% CI, 5%-16%). From 1997 to 2015, the prevalence of degenerative cervical spine disease and degenerative lumbar spine disease increased by 18.3% and 27%, respectively. Pooled prevalence estimates for pain ranged from 35% to 60% and differed by assessment instrument. Of those with a work-related MSD, 12% (277 of 2319 physicians) (95% CI, 7%-18%) required a leave of absence, practice restriction or modification, or early retirement. Heterogeneity was considerable for all crude analyses (mean I^2 = 93.5%) but was lower for sensitivity analyses (mean I^2 = 72.3%). Interventions focused on products and behaviors. Twelve at-risk specialties described a gross lack of awareness and an unmet need for ergonomics education.

CONCLUSIONS AND RELEVANCE Prevalence estimates of work-related MSDs among at-risk physicians appear to be high. Further research is needed to develop and validate an evidence-based applied ergonomics program aimed at preventing these disorders in this population.

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Workers of many occupations bear a health burden associated with disabling musculoskeletal pain and injuries of a work-related etiology, collectively called work-related musculoskeletal disorders (MSDs). These are a group of preventable disorders affecting muscles, tendons, and nerves. Examples include carpal tunnel syndrome, tendinitis, degenerative spine disease, thoracic outlet syndrome, and tension neck syndrome.[1] These diagnoses share common risk factors, such as sustained nonneutral postures and forceful repetitive tasks, often resulting from poor instrumentation design; they manifest with insidious pain that can result in temporary or permanent work disability, if not addressed.

Procedural physicians, such as surgeons and interventional medical specialists, have a high risk for work-related MSDs. This is due to long work hours involving repetitive movements, static and awkward postures, and challenges with instrument design, especially given the rapid rate of innovation in the setting of a diversifying workforce.[1] Ergonomists have described the surgeon's work environment and working conditions as equal to, if not at times harsher than, those of certain industrial workers.[2] This observation is consistent with studies demonstrating higher prevalence estimates of work-related MSDs among at-risk physicians compared with the general population[3] and even labor-intensive occupations, such as coal miners, manufacturing laborers, and physical therapists.[4] Although great strides have been made in industrial ergonomics to reduce the burden of disease, medicine has proven to be a unique challenge and the lack of intervention in this group is now becoming apparent.[2]

The growing prevalence of work-related MSDs among at-risk physicians has been called "an impending epidemic"[5] and "the tip of an iceberg."[6] Numerous cross-sectional studies[5,7-11] report that more than 80% of at-risk physicians experience significant pain when performing procedures; the prevalences of tendinitis[11] and carpal tunnel syndrome[12] appear to be high, but estimates vary widely by study. In addition, conducting research on occupational injuries in physicians using established databases is challenging due to severe underreporting. For instance, in one study[13] of 103 injured surgeons, a mere 19% reported their injury to their institution, despite the fact that 35% performed fewer operations due to the injury.

Per the Association of American Medical Colleges 2014 Physician Specialty Data Book,[14] at-risk physicians comprise 20.4% (175 955 of 860 939 physicians) of the active physician workforce. This workforce is expected to face a shortage by 2025, with a lack of 25 200 to 33 200 surgeons alone, and disability is one contributing factor.[15] Although research has been conducted on burnout,[16] sharps injuries,[17] and other occupational hazards in medicine,[17-19] little attention has been paid to the growing body of literature describing the work-related MSDs forcing these physicians to undergo surgery,[3,20-26] reduce productivity,[25-29] and at times lose their careers.[3,6,20,28] Reliable estimates of the burden of work-related MSDs among these physicians are important for informing the urgency and scope of preventive efforts needed, particularly given the impending workforce shortage.[30,31]

We conducted a systematic review and meta-analysis of published studies among at-risk physicians, with several goals. These include determining (1) the prevalence of work-related MSDs, (2) the disability burden of work-related MSDs, and (3) the scope of interventions aimed at reducing the prevalence of work-related MSDs.

Key Points

Question What is the prevalence of work-related musculoskeletal disorders among at-risk physicians (surgeons and interventionalists)?

Findings Among 21 articles (5828 physicians) included in this systematic review and meta-analysis, the 12-month prevalence estimates for neck, shoulder, back, and upper extremity pain were estimated. The career prevalence estimates for degenerative cervical spine disease, rotator cuff pathology, degenerative lumbar spine disease, and carpal tunnel syndrome were also calculated.

Meaning The prevalence of work-related musculoskeletal disorders among at-risk physicians is comparable to that reported among high-risk workers (eg, laborers); given the impending physician shortage, this problem warrants prompt attention and action.

Methods

Search Strategy and Study Eligibility

A systematic search was conducted in MEDLINE (Ovid), Embase (Elsevier), Web of Science, PubMed (National Center for Biotechnology Information), and 2 clinical trial registries from inception until December 2016, without language restriction. The Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines for meta-analyses and systematic reviews of observational studies were used. Database search algorithms were designed by an expert biomedical librarian. Databases were queried for studies on at-risk physicians, work-related MSDs, and ergonomics. At-risk physicians were defined as surgeons and medical interventionalists. Complete search algorithms for each database are available in the Database Search Algorithms section of the Supplement.

Two of us (S.E. and B.N.T.) independently screened articles, extracted data, and performed the critical appraisal, with discrepancies discussed among the team.[32,33] The principal investigators of ongoing trials were contacted regarding imminent publications. All included articles were published in English or Spanish and were read directly, and citations were screened for articles missed by the search.

Studies were included in the qualitative review if they (1) reported primary data on at-risk physicians and (2) were accepted for publication in peer-reviewed journals. Additional eligibility criteria for inclusion in the quantitative synthesis were as follows: the study (1) reported at least one prevalence estimate for one of the most commonly reported work-related MSDs of the neck, shoulder, back, or upper extremity; (2) reported prevalence estimates for a common interval; and (3) passed critical appraisal. In addition, studies reporting on the prevalence of pain were only included if the pain was assessed using a previously validated instrument, a de novo instrument for which the article reported acceptable validity or reliability scores, or a de novo instrument designed by occupational medicine or ergonomics experts.

Data Extraction and Quality Assessment

Data from each study reporting prevalence estimates were extracted. These included the following: study design, medical specialty, procedural technique, geographic location, sample size, response rate, mean age of physicians, percentage of male physicians, mean caseload of physicians in hours performing procedures per week or number of procedures performed per week, mean number of years in practice of physicians, instrument used for diagnosis or screening, reported prevalence estimates with associated periods of work-related MSDs, and days of work lost or number of physicians requiring a leave of absence, practice restriction or modification, or early retirement due to work-related MSD.

The prevalence estimates for work-related MSDs of the neck, shoulder, back, and upper extremity were recorded. These areas were chosen because they were previously identified as areas of great concern.[34] Tools used to evaluate diagnoses and pain were also recorded.

Data extracted from each study reporting outcomes of ergonomics assessments or interventions included medical specialty, procedural technique, and geographic location. Studies were sorted into one of the following 3 groups: baseline ergonomics assessments, ergonomics products and technology, or education and behavior modification strategies.

The critical appraisal checklist from The Joanna Briggs Institute[35] Reviewers' Manual 2014 was used to assess the quality of each study reporting prevalence estimates (eTable 1 in the Supplement). Low-quality studies were excluded. eTable 2 in the Supplement lists detailed exclusions.

Quantitative Synthesis

Prevalence estimates were calculated by pooling study-specific estimates using the random-effects meta-analytic model by DerSimonian and Laird. Statistical heterogeneity was assessed with the Mantel-Haenszel method and I^2 statistic. Weighted proportions and their 95% CIs were summarized in forest plots. Studies reporting a measure of disability burden or outcomes of ergonomics assessments and interventions underwent textual analysis and were summarized qualitatively.

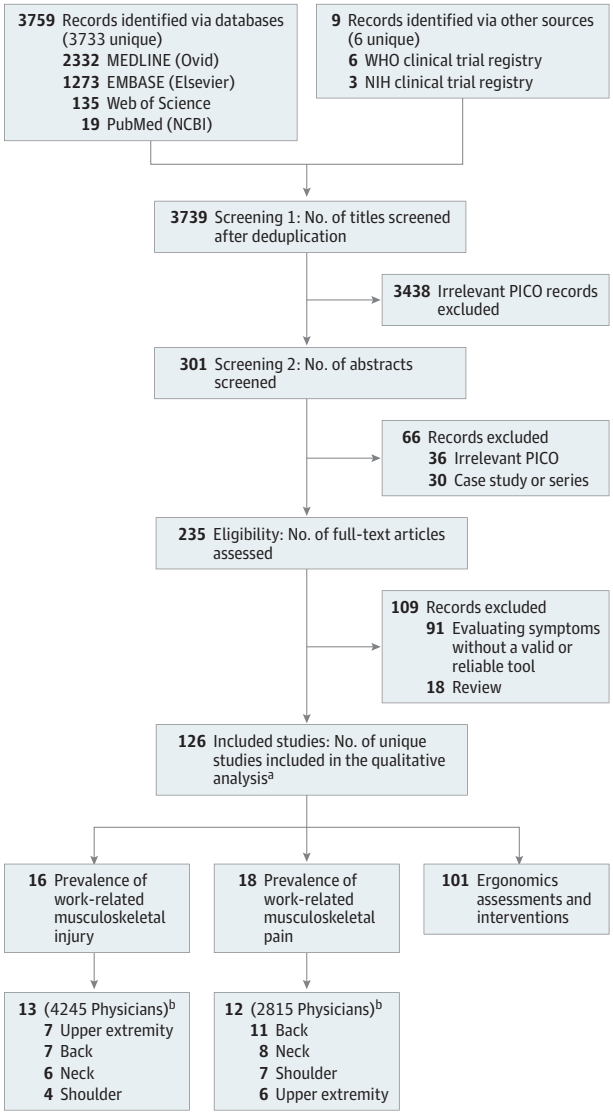
Sensitivity analyses were conducted by stratifying on publication year for pooled injury data and by stratifying on assessment instrument for pooled pain data. We evaluated for differences in rates of injury and pain by specialty and technique using standard nonparametric bivariate methods. Meta-regression was not conducted given an insufficient number of studies with detailed sample data per analysis needed for meaningful results. All statistical tests were 2-sided with α set to .05. A software program (R, version 3.3.2; R Foundation for Statistical Computing) was used for all statistical analyses.

Results

The search returned 3739 unique items. Most were discarded due to nonphysician patient population because many results involved physician management of occupational disorders in the general population (n = 3474). Others were discarded due to a lack of primary data of interest (n = 48) or the lack of a valid and reliable instrument used for evaluation (n = 91). Ultimately, 126 articles met inclusion criteria; 9 articles presented data for multiple outcomes of interest and were added more than once for analysis (**Figure 1**).

Included articles were published between 1974 and 2016 in 23 unique countries. The specialties contributing most to the literature were general surgery (53 of 135 [39.3%]), gynecology (19 of 135 [14.1%]), and urology (17 of 135 [12.6%]). Most articles (68 of 135 [50.4%]) focused on minimally invasive techniques (eTable 3 in the Supplement).

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow Diagram of the Systematic Literature Search and Review Protocol



NCBI indicates National Center for Biotechnology Information; NIH, National Institutes of Health; PICO, population, injury, or context; and WHO, World Health Organization.

[a] Nine articles presented data for multiple outcomes of interest and were added more than once for analysis.

[b] See eTable 2 in the Supplement for study-level reasons for exclusion.

Table. Select Characteristics of Cross-sectional Studies Reporting on Prevalence of Work-Related Musculoskeletal Injuries and Prevalence of Work-Related Musculoskeletal Pain

Source	Outcome	Specialty (Technique)	Geographic Location	No. of Physicians	Age, Mean, y	Male, No. (%)	Case Load/wk	Practice, Mean, y
Adams et al,[36] 2013	Pain	Ob/Gyn (MIS-E)	United States	495	47	249 (50.3)	8 h	18
Alqahtani et al,[11] 2016	Injury, pain	Orthopedic surgery	Global	183	54.9	179 (97.8)	5.8 Cases	22.3
Alqahtani et al,[21] 2016	Injury, pain	Orthopedic surgery	North America	86	49.3	73 (84.9)	NR	15.9
Alzahrani et al,[23] 2016	Injury, pain	Orthopedic surgery	North America	402	51.2	306 (76.1)	NR	18.3
Auerbach et al,[3] 2011	Injury, pain	Orthopedic surgery	United States	561	54	NR	2.8 Cases	NR
Capone et al,[4] 2010	Injury	Multiple	United States	325	48.1	283 (87.1)	NR	12.9
Cass et al,[26] 2014	Injury	Ob/Gyn (MIS-E)	United Kingdom	128	NR	NR	NR	NR
Dhimitri et al,[37] 2005	Pain	Ophthalmology	United States	697	51.9	586 (84.1)	6.8 Cases	19.8
Esser et al,[38] 2007	Pain	Dermatology	United States	17	39.6	12 (70.6)	24.3 h	6.8
Forst et al,[12] 2006	Injury	Multiple	North America	285	46.7	278 (97.5)	NR	14.1
Franasiak et al,[39] 2014	Pain	Multiple (MIS-R)	United States	42	NR	19 (45.2)	5.4 h	3.0[a]
Giberti et al,[40] 2014	Pain	Multiple (MIS-R)	Italy	17	51.3	16 (94.1)	6.0 h	3.0[a]
Goldstein et al,[41] 2004	Injury	Interventional cardiology	United States	423	NR	NR	9.8 Cases	13.8
Healy et al,[42] 2011	Injury	Urology (MIS-E)	United States	122	NR	NR	3.8 h	13
Hyer et al,[43] 2015	Pain	Ophthalmology	United Kingdom	518	48.7	386 (74.5)	8.78h	NR
Kim-Fine et al,[8] 2012	Pain	Ob/Gyn	Global	506	41.9	248 (49.0)	NR	15.9
Kitzmann et al,[44] 2012	Pain	Ophthalmology	United States	94	41.5	62 (66.0)	NR	11.8
Klein et al,[45] 2015	Injury	Interventional cardiology	United States	310	49	276 (89.0)	11.1 Cases	16
Knudsen et al,[46] 2014	Pain	Orthopedic surgery	United States	32	29.5	24 (75.0)	33.8 h	2.9
Lawther et al,[47] 2002	Injury	General surgery (MIS-E)	United Kingdom	50	NR	NR	0.7 Cases	10
Liang et al,[7] 2012	Pain	Dermatology	United States	354	44.5	251 (70.9)	NR	8.9
Liberman et al,[29] 2005	Injury	General surgery (MIS-E)	United States	582	48	520 (89.3)	17 Cases	14.8
Mal and Costello,[48] 2002	Injury	Otolaryngology	United Kingdom	367	51.2	NR	NR	NR
Mohseni-Bandpei et al,[27] 2011	Pain	Multiple	Iran	223	42.6	108 (48.4)	NR	10.5
Rambabu and Suneetha,[49] 2014	Pain	Multiple	India	100	NR	NR	NR	NR
Ross et al,[24] 1997	Injury	Interventional cardiology	United States	385	46.9	367 (95.3)	12.1 Cases	16.1
Sivak-Callcott et al,[20] 2011	Injury	Ophthalmology	United States	130	48	111 (85.4)	13.8 h	16.1
Szeto et al,[9] 2012	Pain	General surgery	Hong Kong	135	34	111 (82.2)	19.1 h	10
Tjiam et al,[10] 2014	Pain	Urology (MIS-E)	the Netherlands	285	46	265 (93.0)	6.45h	12.9
Voss et al,[22] 2017	Injury	General surgery	United States	127	NR	77 (60.6)	NR	7.1

Abbreviations: MIS-E, minimally invasive surgery–endoscopy; MIS-R, minimally invasive surgery–robotic; NR, not recorded; Ob/Gyn, obstetrics and gynecology.

[a] Mean number of years practicing robotic surgery.

Included in the meta-analysis were 21 articles. These encompassed 5828 physicians (mean age, 46.0 years; 78.5% male; 12.8 years in practice; 14.4 hours performing procedures per week). Rates of injury and pain were similar among surgeons compared with interventionalists (eTable 4 in the Supplement), as well as among surgeons with a predominantly open approach compared with minimally invasive surgeons (eTable 5 in the Supplement).

Prevalence of Work-Related Musculoskeletal Injuries

Injury prevalence was described in 16 cross-sectional studies (**Table**). Studies used de novo questionnaires to ask physicians if they had been clinically diagnosed as having various work-related MSDs, with the most common being degenerative cervical spine disease, rotator cuff pathology, degenerative lumbar spine disease, and carpal tunnel syndrome. Given a great breadth of pathologic descriptions for spine disease, an expert in rheumatology and orthopedic surgery outcomes research (Jeffrey N. Katz, MD, MSc, written communication, January 2017) was consulted after data extraction to define degenerative spine disease as any of the following: spondylosis, spondyloarthropathy, herniated or ruptured cervical disc, or radiculopathy. Nonspecific paresthesia and neurapraxia were excluded.

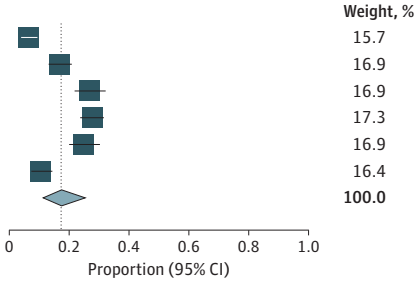
Thirteen of the 16 studies were eligible for the quantitative synthesis (eTable 2 in the Supplement). This resulted in a pooled sample of 4245 physicians, most of whom were orthopedic surgeons (n = 1232), interventional cardiologists (n = 1118), and general surgeons (n = 582), located in North America (n = 3812).

Figure 2. Meta-analyses of the Career Prevalence of Work-Related Musculoskeletal Injuries Among At-Risk Physicians Stratified by Site of Injury

A Degenerative cervical spine disease

Source	Specialty	No. of Events	No. of Physicians	Proportion (95% CI)	Weight, %
Ross et al,[24] 1997	Interventional cardiology	25	385	0.06 (0.04-0.09)	15.7
Goldstein et al,[41] 2004	Interventional cardiology	71	423	0.17 (0.13-0.21)	16.9
Capone et al,[4] 2010	Plastic surgery	87	325	0.27 (0.22-0.32)	16.9
Auerbach et al,[3] 2011	Orthopedic surgery	155	561	0.28 (0.24-0.32)	17.3
Klein et al,[45] 2015	Intervention cardiology	77	310	0.25 (0.20-0.30)	16.9
Alzahrani et al,[23] 2016	Orthopedic surgery	42	402	0.10 (0.08-0.14)	16.4
Random-effects model			**2406**	**0.17 (0.12-0.25)**	**100.0**

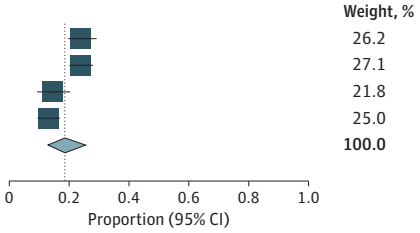
Heterogeneity I^2 = 94.8%, τ^2 = 0.3226, P<.001



B Rotator cuff pathology

Source	Specialty	No. of Events	No. of Physicians	Proportion (95% CI)	Weight, %
Mal and Costello,[48] 2002	Otolaryngology	88	367	0.24 (0.20-0.29)	26.2
Auerbach et al,[3] 2011	Orthopedic surgery	134	561	0.24 (0.20-0.28)	27.1
Alqahtani et al,[11] 2016	Orthopedic surgery	26	183	0.14 (0.09-0.20)	21.8
Alzahrani et al,[23] 2016	Orthopedic surgery	52	402	0.13 (0.10-0.17)	25.0
Random-effects model			**1513**	**0.18 (0.13-0.25)**	**100.0**

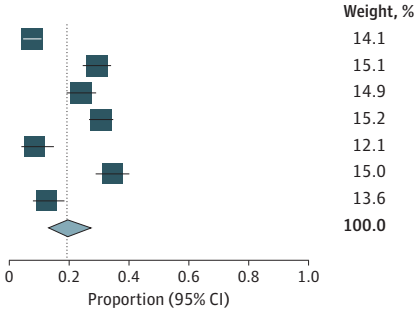
Heterogeneity I^2 = 87.9%, τ^2 = 0.1338, P<.001



C Degenerative lumbar spine disease

Source	Specialty	No. of Events	No. of Physicians	Proportion (95% CI)	Weight, %
Ross et al,[24] 1997	Interventional cardiology	29	385	0.08 (0.05-0.11)	14.1
Goldstein et al,[41] 2004	Interventional cardiology	124	423	0.29 (0.25-0.34)	15.1
Capone et al,[4] 2010	Plastic surgery	78	325	0.24 (0.19-0.29)	14.9
Auerbach et al,[3] 2011	Orthopedic surgery	172	561	0.31 (0.27-0.35)	15.2
Cass et al,[26] 2014	Ob/Gyn (MIS-E)	11	128	0.09 (0.04-0.15)	12.1
Klein et al,[45] 2015	Interventional cardiology	107	310	0.35 (0.29-0.40)	15.0
Alqahtani et al,[11] 2016	Orthopedic surgery	23	183	0.13 (0.08-0.18)	13.6
Random-effects model			**2315**	**0.19 (0.13-0.27)**	**100.0**

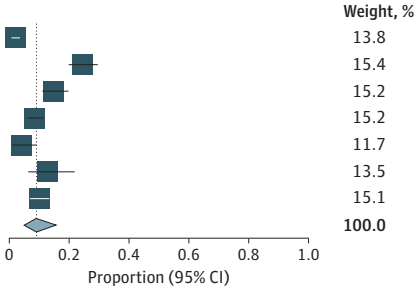
Heterogeneity I^2 = 94.6%, τ^2 = 0.3375, P<.001



D Carpal tunnel syndrome

Source	Specialty	No. of Events	No. of Physicians	Proportion (95% CI)	Weight, %
Liberman et al,[29] 2005	General surgery (MIS-E)	12	582	0.02 (0.01-0.04)	13.8
Forst et al,[12] 2006	Multiple	91	371	0.25 (0.20-0.29)	15.4
Capone et al,[4] 2010	Plastic surgery	49	325	0.15 (0.11-0.19)	15.2
Auerbach et al,[3] 2011	Orthopedic surgery	48	561	0.09 (0.06-0.11)	15.2
Healy et al,[42] 2011	Urology (MIS-E)	5	122	0.04 (0.01-0.09)	11.7
Alqahtani et al,[21] 2016	Orthopedic surgery	11	86	0.13 (0.07-0.22)	13.5
Alzahrani et al,[23] 2016	Orthopedic surgery	40	402	0.10 (0.07-0.13)	15.1
Random-effects model			**2449**	**0.09 (0.05-0.16)**	**100.0**

Heterogeneity I^2 = 94.5%, τ^2 = 0.5999, P<.001



Included were 6 studies[3,4,23,24,41,45] for degenerative cervical spine disease (A), 4 studies[3,11,23,48] for rotator cuff pathology (B), 7 studies[3,4,11,24,26,41,45] for degenerative lumbar spine disease (C), and 7 studies[3,4,12,21,23,29,42] for carpal tunnel syndrome (D).

The overall career prevalence estimate of degenerative lumbar spine disease was 19% (544 of 2449 physicians) (95% CI, 13%-27%) (I^2 = 94.6%) (**Figure 2**). This appeared to increase over time in serial cross-sectional surveys of interventional cardiologists in the Society for Cardiac Angiography and Interventions: Ross et al[24] reported an estimate of 6.5% in 1997, Goldstein et al[41] reported an estimate of 16.8% in 2004, and Klein et al[45] reported an estimate of 24.7% in 2015 (a change of 18.3% over 18 years). When stratified by period, studies published in the past decade resulted in an

estimate of 22% (361 of 1598 physicians) (95% CI, 15%-30%) (I^2 = 93.0%).

The overall career prevalence estimate of rotator cuff pathology was 18% (300 of 1513 physicians) (95% CI, 13%-25%) (I^2 = 87.9%). When stratified by period, studies published in the past decade resulted in an estimate of 17% (212 of 1146 physicians) (95% CI, 10%-26%) (I^2 = 90.4%).

The overall career prevalence estimate of degenerative lumbar spine disease was 19% (544 of 2449 physicians) (95% CI, 5%-16%) (I^2 = 94.5%). This appeared to increase over time in serial cross-sectional surveys of interventional cardiologists in the Society for Cardiac Angiography and Interventions: Ross et al[24] reported an estimate of 8% in 1997, Goldstein et al[41] reported an estimate of 29% in 2004, and Klein et al[45] reported an estimate of 35% in 2015 (a change of 27% over 18 years). When stratified by period, studies published in the past decade resulted in an estimate of 21% (391 of 1507 physicians) (95% CI, 15%-30%) (I^2 = 92.1%).

The overall career prevalence estimate of carpal tunnel syndrome was 9% (256 of 2449 physicians) (95% CI, 5%-16%) (I^2 = 94.5%). When stratified by period, studies published in the past decade resulted in an estimate of 12% (244 of 1867 physicians) (95% CI, 7%-18%) (I^2 = 91.7%).

Prevalence of Work-Related Musculoskeletal Pain

Pain prevalence was described in 18 cross-sectional studies (Table). Studies used 5 validated tools to measure pain prevalence and subsequent disability (eTable 6 in the Supplement).

Twelve of the 18 studies were eligible for the quantitative synthesis (eTable 2 in the Supplement). This resulted in a pooled sample of 2815 physicians, most of whom were orthopedic surgeons (n = 1264), gynecologists (n = 495), and dermatologists (n = 371), located in North America (n = 1989).

The overall 12-month prevalence estimate of neck pain was 60% (1131 of 1921 physicians) (95% CI, 47%-72%) (I^2 = 96.0%), and the overall 12-month prevalence estimate of shoulder pain was 52% (802 of 1360 physicians) (95% CI, 43%-61%) (I^2 = 86.8%). These results are shown in **Figure 3**. The overall 12-month prevalence estimate of back pain was 49% (1233 of 2254 physicians) (95% CI, 36%-62%) (I^2 = 96.8%), and the overall 12-month prevalence estimate of upper extremity pain was 35% (588 of 1343 physicians) (95% CI, 21%-52%) (I^2 = 96.6%). These results are shown in **Figure 4**.

Heterogeneity was considerable for all crude analyses (mean I^2 = 93.5%). It was lower on sensitivity analyses (mean I^2 = 72.3%).

Five studies used the Nordic Musculoskeletal Questionnaire. For these, the 12-month prevalence estimate of neck pain was 65% (737 of 1058 physicians) (95% CI, 54%-76%) (I^2 = 89.9%), shoulder pain was 52% (647 of 1058 physicians) (95% CI, 41%-63%) (I^2 = 88.8%), back pain was 59% (715 of 1058 physicians) (95% CI, 45%-71%) (I^2 = 92.0%), and upper extremity pain was 39% (527 of 1058 physicians) (95% CI, 25%-55%) (I^2 = 94.9%).

Four studies used the Physical Discomfort Survey. For these, the 12-month prevalence estimate of neck pain was 38% (215 of 561 physicians) (95% CI, 34%-42%) (I^2 not applicable), and back pain was 28% (189 of 671 physicians) (95% CI, 25%-32%) (I^2 = 0.0%).

Three studies used a de novo questionnaire. For these, the 12-month prevalence estimate of neck pain was 59% (179 of 302 physicians) (95% CI, 54%-65%) (I^2 = 0.0%), shoulder pain was 51% (155 of 302 physicians) (95% CI, 46%-57%) (I^2 = 0.0%), back pain was 60% (329 of 525 physicians) (95% CI, 45%-73%) (I^2 = 86.7%), and upper extremity pain was 21% (61 of 285 physicians) (95% CI, 17%-27%) (I^2 not available).

Disability Burden

A measure of disability burden was reported in 10 studies. Few studies reported similar specific measures, so a general measure of the number of affected physicians over a range of severity was calculated. Overall, 12% (277 of 2319 physicians) (95% CI, 7%-18%) (I^2 = 92.3%) of physicians required a leave of absence, practice restriction or modification, or early retirement due to work-related MSD (eFigure in the Supplement).

Ergonomics Assessments and Interventions

Ergonomics assessments and interventions were described in 101 articles, about half of which (n = 50) were from the United States. Germany has published more studies (n = 4) directly related to policy and regulatory processes compared with other countries. All studies used short-term measures, such as symptoms experienced or electromyographic data collected during procedures, with minimal time points. No study design included long-term surveillance for work-related MSDs. Thirty-eight studies focused on ergonomics devices (eg, floor mats and supportive furniture) and ergonomically improved medical technology (eg, alternative video displays for microsurgery), 37 studies focused on education and behavioral modifications (eg, targeted stretching microbreaks), and the remainder consisted of baseline ergonomics assessments, details of which are beyond the scope of this systematic review and meta-analysis.

Several studies[5,50-52] state that surgeons and interventionalists lack awareness of applied ergonomics recommendations. Twelve at-risk specialties from 8 countries have published at least one article describing a need for ergonomics education during medical training. Specialties included dermatology,[7] gastroenterology,[50] general surgery,[5,51] gynecology,[52] interventional cardiology,[53] interventional radiology,[53] neurosurgery,[54] ophthalmology,[43] orthopedic surgery,[13] otolaryngology,[55,56] plastic surgery,[4] and urology.[10,57] Countries include Australia,[58] China,[57] Germany,[59] Italy,[60-62] the Netherlands,[63] Spain,[64] the United Kingdom,[65,66] and the United States.[43,50,51] A few studies[39,50,64] have found that ergonomics education during medical training appears feasible, accepted, and effective at changing behaviors and reducing symptoms.

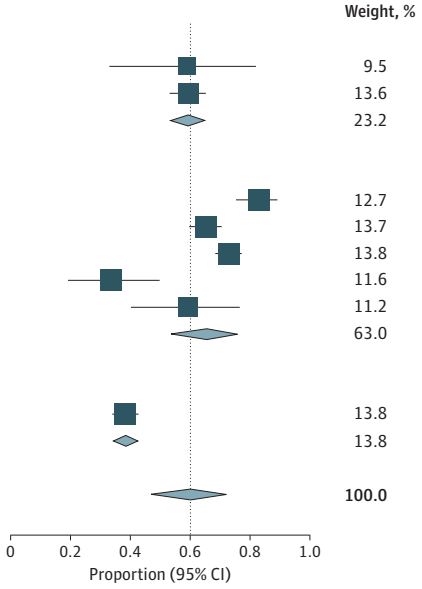
Discussion

This systematic review and meta-analysis of work-related MSDs among at-risk physicians found (1) high prevalence estimates of work-related MSDs, (2) a range of disability burden that included early retirement, and (3) a high demand for intervention, with poor supply. These findings are worrisome in thecontext of an impending shortage[30,31] of surgeons and interventionalists and the large public investment required to train such specialists.

Figure 3. Meta-analyses of the 12-Month Prevalence of Work-Related Neck Pain and Shoulder Pain Among At-Risk Physicians Stratified by Site of Pain and Assessment Instrument

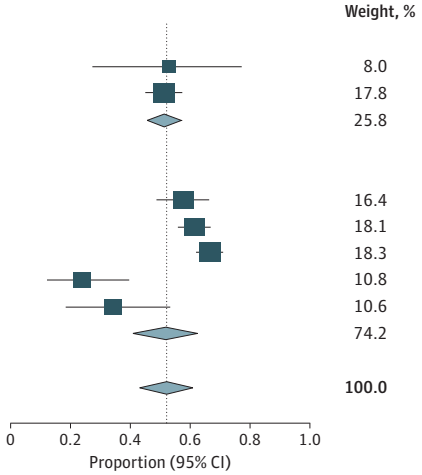
A Neck pain stratified by assessment instrument

Source	Specialty	No. of Events	No. of Physicians	Proportion (95% CI)	Weight, %
De novo					
Esser et al,[38] 2007	Dermatology	10	17	0.59 (0.33-0.82)	9.5
Tjiam et al,[10] 2014	Urology (MIS-E)	169	285	0.59 (0.53-0.65)	13.6
Random-effects model			**302**	**0.59 (0.54-0.65)**	23.2
Heterogeneity I^2 = 0%, τ^2 = 0, P = .97					
NMQ					
Szeto et al,[9] 2012	General surgery	112	135	0.83 (0.76-0.89)	12.7
Liang et al,[7] 2012	Dermatology	231	354	0.65 (0.60-0.70)	13.7
Adams et al,[36] 2013	Ob/Gyn (MIS-E)	361	495	0.73 (0.69-0.77)	13.8
Franasiak et al,[39] 2014	Multiple (MIS-R)	14	42	0.33 (0.20-0.50)	11.6
Knudsen et al,[46] 2014	Orthopedic surgery	19	32	0.59 (0.41-0.76)	11.2
Random-effects model			**1058**	**0.65 (0.54-0.76)**	63.0
Heterogeneity I^2 = 89.9%, τ^2 = 0.2606, P<.001					
PDS					
Auerbach et al,[3] 2011	Orthopedic surgery	215	561	0.38 (0.34-0.42)	13.8
Random-effects model			561	0.38 (0.34-0.42)	13.8
Heterogeneity not applicable for a single study					
Random-effects model			**1921**	**0.60 (0.47-0.72)**	**100.0**
Heterogeneity I^2 = 96.0%, τ^2 = 0.5165, P<.001					



B Shoulder pain stratified by assessment instrument

Source	Specialty	No. of Events	No. of Physicians	Proportion (95% CI)	Weight, %
De novo					
Esser et al,[38] 2007	Dermatology	9	17	0.53 (0.28-0.77)	8.0
Tjiam et al,[10] 2014	Urology (MIS-E)	146	285	0.51 (0.45-0.57)	17.8
Random-effects model			**302**	**0.51 (0.46-0.57)**	25.8
Heterogeneity I^2 = 0%, τ^2 = 0, P = .89					
NMQ					
Szeto et al,[9] 2012	General surgery	78	135	0.58 (0.49-0.66)	16.4
Liang et al,[7] 2012	Dermatology	218	354	0.62 (0.56-0.67)	18.1
Adams et al,[36] 2013	Ob/Gyn (MIS-E)	330	495	0.67 (0.62-0.71)	18.3
Franasiak et al,[39] 2014	Multiple (MIS-R)	10	42	0.24 (0.12-0.39)	10.8
Knudsen et al,[46] 2014	Orthopedic surgery	11	32	0.34 (0.19-0.53)	10.6
Random-effects model			**1058**	**0.52 (0.41-0.63)**	74.2
Heterogeneity I^2 = 88.8%, τ^2 = 0.2007, P<.001					
Random-effects model			**1360**	**0.52 (0.43-0.61)**	**100.0**
Heterogeneity I^2 = 86.8%, τ^2 = 0.1665, P<.001					



Included were 8 studies[3,7,9,10,36,38,39,46] for neck pain (A) and 7 studies[7,9,10,36,38,39,46] for shoulder pain (B). MIS-E indicates minimally invasive surgery–endoscopy; MIS-R, minimally invasive surgery–robotic; NMQ, Nordic Musculoskeletal Questionnaire; Ob/Gyn, obstetrics and gynecology; and PDS, Physical Discomfort Survey.

This study builds on recent work demonstrating high prevalence estimates of burnout,[16] depression,[67,68] and attrition[69] among physicians during and after training. When considered together, these data suggest that some aspects of medical culture may be detrimental to the mental, emotional, and physical health and career longevity of physicians and subsequently may be detrimental to the volume and quality of patient care. These findings represent the first synthesis of the evidence on an important topic facing many physicians.

This study found that at-risk physicians bear a large burden of work-related MSDs. To illustrate, we found 12-month prevalence estimates for work-related musculoskeletal pain of the neck, shoulder, back, and upper extremity of 65%, 52%, 59%, and 39%, respectively, when the standardized Nordic Musculoskeletal Questionnaire was used for assessment (Figure 3 and Figure 4). Studies using this same questionnaire found mostly comparable 12-month prevalence estimates among workers in high-risk, labor-intensive occupations. For instance, a study[70] of 996 unionized apprentice construction workers in the United States found 12-month prevalence estimates for the neck, shoulder, back, and upper extremity of 31.8%, 27.9%, 54.4%, and 42.4%, respectively. For

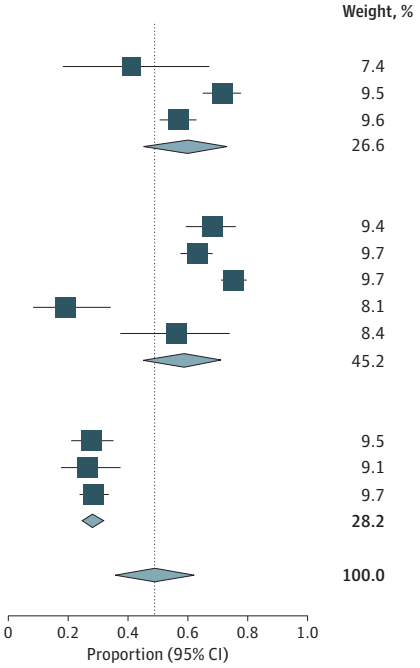
Figure 4. Meta-analyses of the 12-Month Prevalence of Work-Related Back Pain and Upper Extremity Pain Among At-Risk Physicians Stratified by Site of Pain and Assessment Instrument

A Back pain stratified by assessment instrument

Source	Specialty	No. of Events	No. of Physicians	Proportion (95% CI)	Weight, %
De novo					
Esser et al,[38] 2007	Dermatology	7	17	0.41 (0.18-0.67)	7.4
Mohseni-Bandpei et al,[27] 2011	Multiple	160	223	0.72 (0.65-0.78)	9.5
Tjiam,[10] 2014	Urology (MIS-E)	162	285	0.57 (0.51-0.63)	9.6
Random-effects model			525	0.60 (0.45-0.73)	26.6
Heterogeneity I^2 = 86.7%, τ^2 = 0.213, P<.001					
NMQ					
Szeto et al,[9] 2012	General surgery	92	135	0.68 (0.60-0.76)	9.4
Liang et al,[7] 2012	Dermatology	223	354	0.63 (0.58-0.68)	9.7
Adams et al,[36] 2013	Ob/Gyn (MIS-E)	374	495	0.76 (0.72-0.79)	9.7
Franasiak et al,[39] 2014	Multiple (MIS-R)	8	42	0.19 (0.09-0.34)	8.1
Knudsen et al,[46] 2014	Orthopedic surgery	18	32	0.56 (0.38-0.74)	8.4
Random-effects model			**1058**	**0.59 (0.45-0.71)**	45.2
Heterogeneity I^2 = 92%, τ^2 = 0.3222, P<.001					
PDS					
Alqahtani et al,[11] 2016	Orthopedic surgery	51	183	0.28 (0.22-0.35)	9.5
Alqahtani et al,[21] 2016	Orthopedic surgery	23	86	0.27 (0.18-0.37)	9.1
Alzahrani et al,[23] 2016	Orthopedic surgery	115	402	0.29 (0.24-0.33)	9.7
Random-effects model			**671**	**0.28 (0.25-0.32)**	**28.2**
Heterogeneity I^2 = 0%, τ^2 = 0, P = .94					
Random-effects model			**2254**	**0.49 (0.36-0.62)**	**100.0**
Heterogeneity I^2 = 96.8%, τ^2 = 0.7534, P<.001					

B Upper extremity pain stratified by assessment instrument

Source	Specialty	No. of Events	No. of Physicians	Proportion (95% CI)	Weight, %
NMQ					
Szeto et al,[9] 2012	General surgery	82	135	0.61 (0.52-0.69)	17.5
Liang et al,[7] 2012	Dermatology	131	354	0.37 (0.32-0.42)	18.0
Adams et al,[36] 2013	Ob/Gyn (MIS-E)	301	495	0.61 (0.56-0.65)	18.1
Franasiak et al,[39] 2014	Multiple (MIS-R)	7	42	0.17 (0.07-0.31)	14.6
Knudsen et al,[46] 2014	Orthopedic surgery	6	32	0.19 (0.07-0.36)	14.1
Random-effects model			**1058**	**0.39 (0.25-0.55)**	82.2
Heterogeneity I^2 = 94.9%, τ^2 = 0.4795, P<.001					
De novo					
Tjiam et al,[10] 2014	Urology (MIS-E)	61	285	0.21 (0.17-0.27)	17.8
Random-effects model			**285**	**0.21 (0.17-0.27)**	17.8
Heterogeneity not applicable for a single study					
Random-effects model			**1343**	**0.35 (0.21-0.52)**	**100.0**
Heterogeneity I^2 = 96.6%, τ^2 = 0.6849, P<.001					



Included were 11 studies[7,9-11,21,23,27,36,38,39,46] for back pain (A) and 6 studies[7,9,10,36,39,46] for upper extremity pain (B). MIS-E indicates minimally invasive surgery–endoscopy; MIS-R, minimally invasive surgery–robotic; NMQ, Nordic Musculoskeletal Questionnaire; Ob/Gyn, obstetrics and gynecology; and PDS, Physical Discomfort Survey.

409 Portuguese nurses, these estimates were 50.1%, 37.8%, 63.1%, and 28.4%.[71] For 217 Nigerian physical therapists, these estimates were 21.1%, 22.2%, 69.8%, and 20.6%.[72] This epidemiologic burden translates to disability burden, with severe economic ramifications.

More people are disabled from working due to work-related MSDs than from any other group of diseases.[73] In health care workers, work-related MSDs are the number one cause of absenteeism.[74] The Bureau of Labor Statistics of the US Department of Labor estimates that 62% of all worker injuries and 32% of missed days from work are secondary to work-related MSDs: this amounts to an estimated economic impact of $13 to $20 billion every year.[1] The economic burden of work-related MSDs has not yet been reliably defined for physicians.

This study found that 12% of physicians with work-related MSDs require a leave of absence, practice restriction or modification, or early retirement. A lack of standardized reporting across studies precluded a more meaningful measure of disability burden, but the primary literature is telling. For

instance, Auerbach et al[3] reported a career prevalence of 27.6% for cervical radiculopathy among orthopedic surgeons, of whom 10.7% required surgical intervention and 18.9% required time off work, ranging from days to forced early retirement. Among ophthalmologists, Sivak-Callcott et al[20] reported a career prevalence of 31.3% for symptomatic bulging or herniated spinal discs; of the entire sample, 42.5% had to modify their practice due to pain, 7.6% required surgical treatment, and 9.2% were forced to cease practicing entirely.

The qualitative portion of the analysis discovered a demand for ergonomics education. Specifically, 12 specialties from 8 countries explicitly described a need for such applied education. This is supported by reports of low awareness levels of occupational injury, ranging from 11% to 41.3%.[5,51] Furthermore, 85% of at-risk physicians are concerned by work-related MSDs and resulting disability, and more than 90% state that formal ergonomics education should be standard during training, yet only 6.9% to 17% report receiving any ergonomics education during their training, most of which is described as sporadic, informal intraoperative directives.[39,50]

Last, this systematic review and meta-analysis found evidence that procedural physicians do indeed appear to be at higher risk than nonprocedural physicians. For example, Healy et al[42] found that endourologists reported more hand and wrist problems than psychiatrists, Mal and Costello[48] demonstrated that otolaryngologists experience impingement syndrome more frequently than endocrinologists, Kim-Fine et al[8] determined that vaginal surgeons reported a higher rate of work-related MSDs compared with primary care physicians, and Kitzmann et al[44] reported a higher prevalence of neck, back, and upper extremity pain among ophthalmologists compared with family medicine physicians.

When interpreting the results of the quantitative synthesis, it is important to remember that heterogeneity was high for all analyses. A moderate amount of this heterogeneity is explained by differences in the sensitivity of instruments used for MSD evaluation. This is evidenced by the lower heterogeneity scores on subgroup analysis by instrument. Additional heterogeneity may be explained by differences in the mean age of physicians, workload, number of years in practice, proportion that are male, and geographic location among study samples. Although differences in these variables are grossly evident in the Table, determining whether any one variable independently and significantly accounts for heterogeneity was not possible because there was an insufficient number of studies for meta-regression. When more studies are available, this systematic review and meta-analysis may be updated and improved with such an analysis.

While the etiology of the heterogeneity should be determined, its existence does not render the present systematic review and meta-analysis inappropriate for 2 reasons. First, our strict protocol only pools study outcomes that are highly qualitatively homogeneous. Second, the magnitudes of all study estimates are high enough to be meaningful, such that the summary effect estimate is informative, irrespective of variability. Even though the 95% CI for the 12-month prevalence of neck pain is wide at 47% to 72%, the lower boundary of 47% is concerning enough to warrant further study and improved awareness efforts given that other high-risk occupations with similar or even lower prevalence rates receive training and support for preventing injury. These results are particularly meaningful because of our use of a conservative random-effects model.

Limitations

Despite the important strengths of this systematic review and meta-analysis, the bias assessment of the primary literature revealed several limitations. First is selection bias. Of the 30 cross-sectional studies describing prevalence, all 30 used convenience sampling, only 10 achieved a response rate of at least 65%, and only 4 were analytic cross-sectional studies. The rest were descriptive studies without reference groups.

A second limitation is misclassification bias. All primary data were acquired through self-report instruments.

The third limitation is social desirability bias. Some studies administered surveys in-person and to very small cohorts of peers at the same institution.

Finally, we were unable to assess for publication bias. This was due to the setting of an insufficient number of studies needed for meaningful results.

Future Directions

Considering the high prevalence of work-related MSDs, subsequent disability burden, and clear demand for ergonomics education by numerous specialties, this systematic review and meta-analysis underscores the need for the development and validation of an evidence-based applied ergonomics program. Education on workplace safety and ergonomics has been shown to be effective at increasing awareness and reducing risk factors in other occupations,[75-78] but it is often not sufficient on its own. Therefore, future research should involve collaborating with experts in ergonomics and occupational medicine to develop and examine a broader, systems-based approach to ergonomics programs within the surgical or interventional suite.[79,80]

Ultimately, this work should be integrated with research on preventing surgeon burnout and attrition given shared risk factors. With these joint efforts, perhaps using innovative physician well-being programs[81,82] as vehicles, we may be able to better protect the health and career longevity of our workforce and subsequently deliver superior care for our patients.

Conclusions

This systematic review and meta-analysis found that the prevalence of work-related MSDs among at-risk physicians is high and that no overarching intervention exists. At a time when practitioners are beginning to address burnout and other facets of medical culture contributing to attrition, suicide, and other markers of poor well-being, we must not forget the physical demands of a career in medicine. Like workers in other occupations, physicians have a right to practice their profession in a safe environment. The health and career longevity of our trainees, our colleagues, and ourselves rely on our dedication to bringing awareness and action to this issue.

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Acquisition, analysis, or interpretation of data: Epstein, Sparer, Tran, Ruan, Dennerlein.
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