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Degenerative Lumbar Spine Disease: Estimating Global Incidence and Worldwide Volume

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Abstract

Study Design: Meta-analysis-based calculation.

Objectives: Lumbar degenerative spine disease (DSD) is a common cause of disability, yet a reliable measure of its global burden does not exist. We sought to quantify the incidence of lumbar DSD to determine the overall worldwide burden of symptomatic lumbar DSD across World Health Organization regions and World Bank income groups.

Methods: We used a meta-analysis to create a single proportion of cases of DSD in patients with low back pain (LBP). Using this information in conjunction with LBP incidence rates, we calculated the global incidence of individuals who have DSD and LBP (ie, their DSD has neurosurgical relevance) based on the Global Burden of Disease 2015 database.

Results: We found that 266 million individuals (3.63%) worldwide have DSD and LBP each year; the highest and lowest estimated incidences were found in Europe (5.7%) and Africa (2.4%), respectively. Based on population sizes, low- and middle-income countries have 4 times as many cases as high-income countries. Thirty-nine million individuals (0.53%) worldwide were found to have spondylolisthesis, 403 million (5.5%) individuals worldwide with symptomatic disc degeneration, and 103 million (1.41%) individuals worldwide with spinal stenosis annually.

Conclusions: A total of 266 million individuals (3.63%) worldwide were found to have DSD and LBP annually. Significantly, data quality is higher in high-income countries, making overall quantification in low- and middle-income countries less complete. A global effort to address degenerative conditions of the lumbar spine in regions with high demand is important to reduce disability.

Keywords

epidemiology, global, spine degeneration, incidence, volume, worldwide

Introduction

Degenerative disease of the lumbar spine is a significant cause of disability in the world; it encompasses conditions such as spondylolisthesis, disc degeneration, and lumbar spinal stenosis. Associated with a variety of clinical symptoms, including lower extremity pain, weakness, and low back pain (LBP) of varying levels of severity, lumbar degenerative spine disease (DSD) can lead to a reduction in the quality of life. Demonstrated geographic disparities for DSD[1] may be associated with disparities in socioeconomic status and access to medical care. In the 2010 Global Burden of Disease (GBD) Study,[1] LBP was ranked highest of the 291 conditions studied in terms of years lost to disability, with 83 million disability-adjusted life years lost in 2010.[1]

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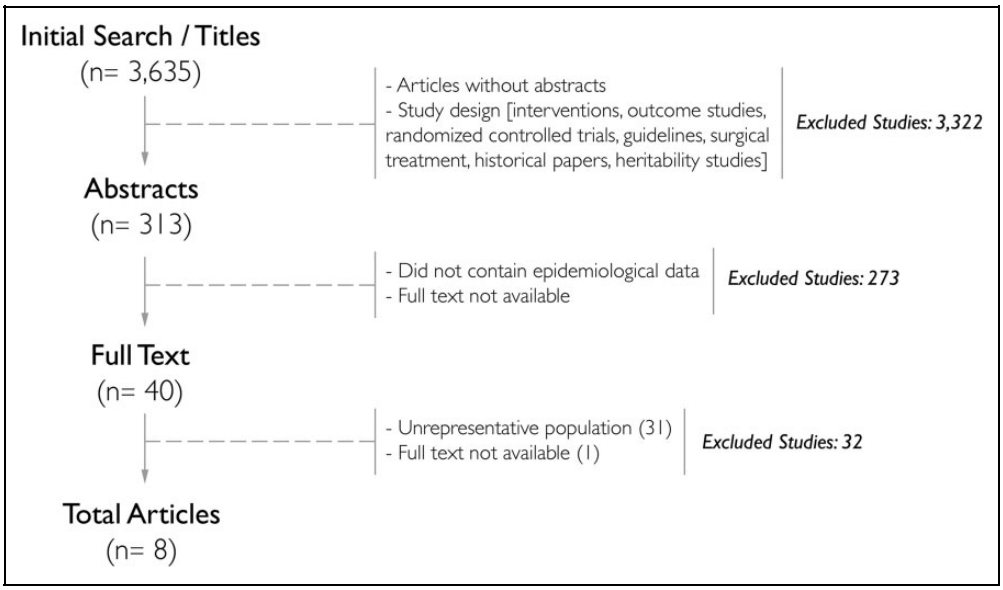

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart: PubMed literature search on degenerative spine disease and back or neck pain.

Numerous studies[2-44] have quantified (incidence or prevalence) DSD; however, the combination of sparse high-quality population-based data, competing disease definitions, and specific population samples, coupled with limited literature resulting from underdiagnosis and underreporting of lumbar DSD in resource-poor settings, have hindered the ability to produce a global estimate. Understanding the burden of lumbar DSD is essential to begin formulating a coordinated, multinational public health effort. In this report, we aggregate data through a systematic review of the literature to generate an approximation of region-specific incidence via a meta-analysis, ultimately culminating in a global estimation of lumbar DSD within the context of LBP.

Methods

Literature Search

A literature search was performed using PubMed and EMBASE in January 2016, following guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[45] The aim of our search was to identify English-language studies with large sample size (both population and hospital based) that reported the epidemiology of DSD within populations having back or neck pain. Including patients with back or neck pain enabled us to focus on neurologically relevant (ie, not strictly age-related) DSD. MeSH and title/abstract keywords were included to maximize the inclusion of any article that related to the volume or the burden (disability-adjusted life years [DALY], years of life lost [YLL], or years lost due to disease [YLD]) of DSD. The full list of search terms can be found in the appendix. Studies without abstracts and those with inappropriate study designs were excluded (Figure 1).

Two authors (VMR, SSS) screened the titles and abstracts of the resulting articles. Articles that contained epidemiological data and met the DSD pathological inclusion criteria (ie, spondylosis, disc degeneration, disc narrowing, degenerative scoliosis, disc herniation, spondylolisthesis, and spinal stenosis) were included. Pathological criteria were determined prior to article screening; we excluded pathologies relating to aging (eg, osteoporosis), autoimmune disease (eg, rheumatoid arthritis), and congenital disorders (eg, juvenile idiopathic scoliosis). The term *degenerative disease* has been previously described as ambiguous,[46] which created complications when attempting to define DSD. Our selection criteria aimed to include pathologies that are commonly classified as DSD.[47] Throughout the abstract and full-text review process, reviewers evaluated articles separately. To ensure selection accuracy and to avoid misrepresentation of populations and pathologies, a subset of articles was jointly reviewed as a form of an interrater reliability test. Discrepancies between article inclusion and exclusion were resolved by a third author (AR or MCD).

Full-text papers were acquired, and data extraction was performed. If necessary, additional articles were excluded based on the exclusion criteria noted in Figure 1. Articles were only included if the epidemiological data defined specific lumbar DSD pathologies presenting in subjects with LBP. Articles that presented epidemiological data on just LBP or just lumbar DSD were excluded. Other exclusion criteria are indicated in Figure 1. Data extraction was performed and results were pooled using MedCalc software version 15.1 (MedCalc Software, Ostend, Belgium) to conduct the meta-analysis.

Meta-Analysis and Calculations

To calculate the overall incidence of lumbar DSD within LBP, a model was designed that exploited multiple sources,

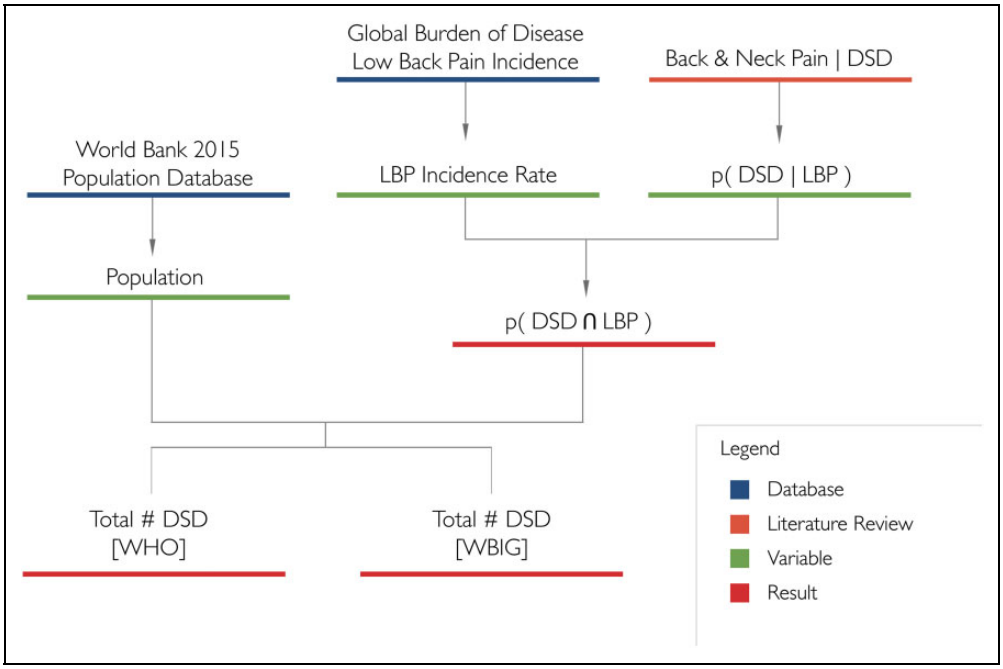

Figure 2. Degenerative spine disease incidence calculations.

including literature reviews, the GBD initiative, and the World Bank (WB) population database (https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups). First, data on the incidence (per 100 000) of LBP was obtained from the Institute of Health Metrics and Evaluation (IHME) GBD 2015 database.[48] The database did not account for countries not recognized by the WB and World Health Organization (WHO) regions. Reported data was representative of both sexes and all ages. Incidence values were adjusted based on 2015 WB population metadata and then reported as a proportion, p(LBP).

Next, the epidemiological data obtained from the second systematic review was pooled with random-effects inverse probability weight to estimate the probability of lumbar DSD among those presenting with LBP: p(DSD|LBP). To determine joint proportion of lumbar DSD and LBP, p(DSD∩LBP), the proportion of LBP—p(LBP)—was multiplied by the proportion of lumbar DSD within LBP populations, p(DSD|LBP). The methodology for calculations is presented in Figure 2 with calculations as follows:

$$\mathrm{p}(\mathrm{DSD} \cap \mathrm{LBP}) = \mathrm{p}(\mathrm{LBP}) \times p(\mathrm{DSD}|\mathrm{LBP}).$$

The incidence of lumbar DSD and LBP was calculated by multiplying p(DSD∩LBP) by the total population of each country obtained from the 2015 WB population metadata. To deliver a simplified geographic breakdown, total incidence results were organized by country into their respective WHO regions (Figure 3).[49] The Region of Americas was further divided into United States and Canada (AMR-US/Can) and Latin America (AMR-L). Results were also presented by income group (low, middle, high) using categorizations of the World Bank gross national income per capita. To create a global and regional incidence, the number of lumbar DSD and LBP cases for each country in a given region was totaled prior to dividing it by a region's total population for countries represented by the GBD data. This proportion was then multiplied by more accurate regional population figures. This approach weighed countries with larger populations more heavily, and error propagation was addressed to generate accurate 95% confidence intervals.

Finally, within the studies analyzed, spondylolisthesis, spinal stenosis, and disc degeneration were the most prevalent lumbar DSD pathologies. Therefore, a proportion was created—p(DX|LBP)—with DX referring to each of the aforementioned pathologies, to obtain their global incidence. Studies used for proportion calculations are presented in Table 1.

Results

Search Results

The literature search produced 3635 results. After thorough review (Figure 1), 40 articles underwent full-text review. Thirty-one studies were excluded from our systematic review because the study population was unrepresentative. One study was excluded because full text was unavailable and the abstract did not contain enough information to include in our incidence equation. Eight studies[11,50-55,63] were analyzed to formulate proportions and ultimately estimate the global incidence of lumbar DSD. A majority of these studies were hospital-based (6/8; 75%)[50-55] and the remaining 2 were population and community based. Most of these studies were derived from high-income countries (HICs) (88%) and most were from the European region (EUR; 4/8, 50%).[11,51,53,55] This was followed

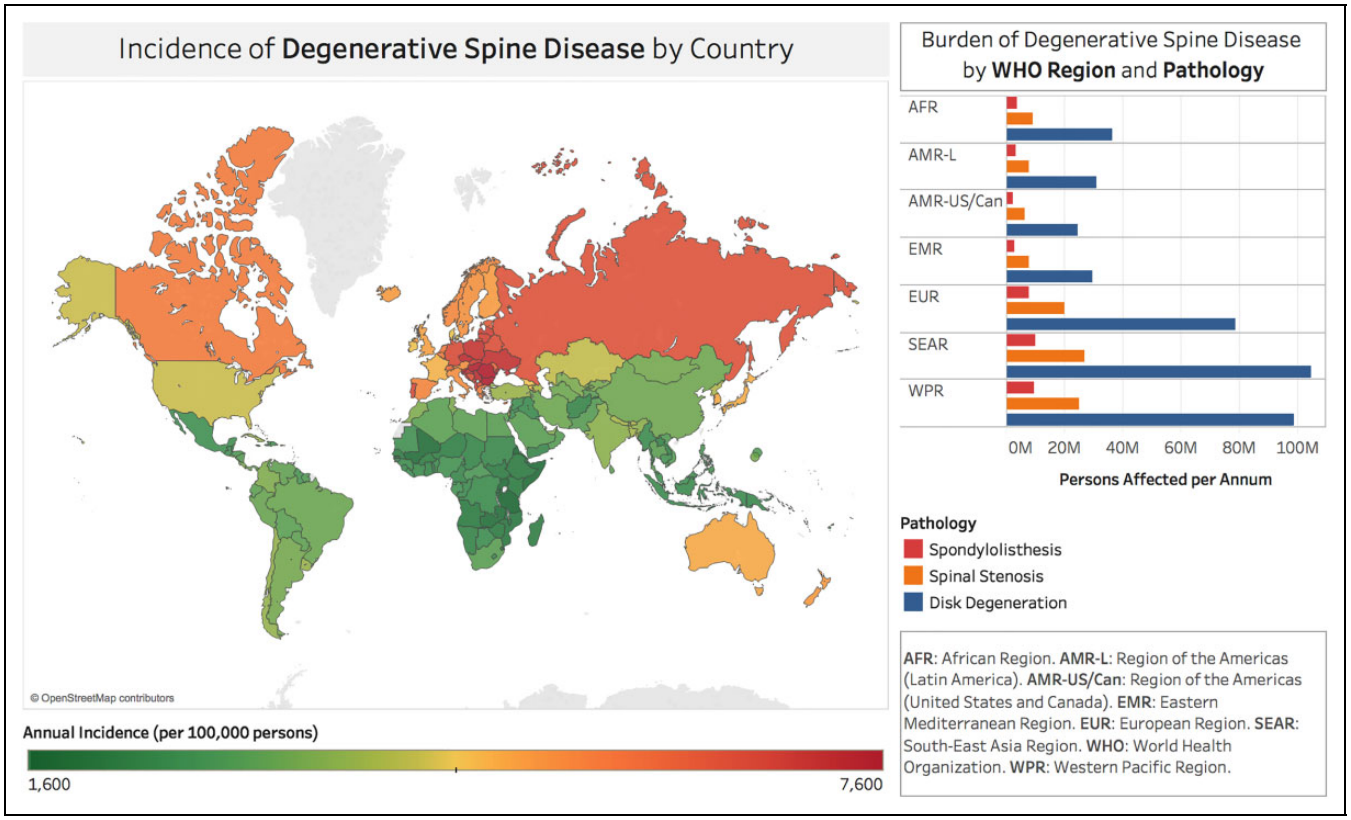

Figure 3. Incidence rates of degenerative spine disease/low back pain in World Bank and World Health Organization recognized countries.

by the North American region (AMR US/Can; 2/8, 25%). The last 2 studies were from the Southeast Asia region (SEAR) and the Eastern Mediterranean region (EMR). In studies where the population was defined, the age range was from 10 to 91 years, with 2 studies describing the age as all inclusive. Of the 8 studies in total, 5 were cross-sectional analyses (5/8, 62.5%), 2 were prospective (2/8, 25%), and 1 was retrospective (1/8, 12.5%). An overview of studies used to create the proportions is found in Table 1, which indicates which studies were used in each calculation.

Epidemiological Findings

We found that 266 million individuals (3.63%) worldwide are diagnosed with lumbar DSD yearly; the highest estimated incidence was in Europe (5.7%; 5668 per 100 000) and the lowest estimated incidence was in Africa (2.4%). In total, low- and middle-income countries (LMICs) had nearly 4 times as many cases as HICs of DSD and LBP (Table 2). Thirty-nine million individuals (0.53%) worldwide were found to be diagnosed with spondylolisthesis yearly, with the highest estimated incidence in Europe (0.83%) and lowest in Africa (0.36%). According to the compiled studies, LMICs had nearly 3.5 times the incidence of spondylolisthesis and LBP than HICs (Table 3). This data indicates that nearly 400 million individuals are diagnosed with pathologic disc degeneration worldwide yearly (5.5%); the estimated incidence was highest in Europe (8.6%) and lowest in Africa (3.7%). LMICs had nearly 3.5 times the incidence of disc degeneration and LBP than HICs (Table 2). A total of 102 million individuals (1.4%) were found to be diagnosed with spinal stenosis worldwide yearly, with the highest estimated incidence in Europe (2.2%) and lowest in Africa (0.94%). LMICs had nearly 3.5 times greater incidence of spinal stenosis and LBP than HICs (Table 3). Figure 3 demonstrates a global burden of disease map depicting the incidence of lumbar DSD and LBP, that is, p(DSD∩LBP).

Discussion

We have determined, using a global model, an estimate of the incidence of symptomatic adult lumbar DSD with LBP; we estimate that approximately 266 million cases of lumbar DSD and LBP occur worldwide each year. Although the incidence of DSD and LBP was estimated to be highest in Europe and North America, the greatest overall volume of DSD and LBP would be seen in Southeast Asia and the Western Pacific. Interestingly, this finding can be supported through the India-based study, which had the greatest calculated p(DSD|LBP).[54]

This estimation is a stepping stone to outlining the global neurosurgical needs. Although surgical pathology is estimated to represent 30% of the global burden of disease, access to surgical care is outside the grasp of much of the global population, specifically those in LMICs. The WHO estimates that nearly 11% to 15% of the world's disability is caused by

Table 1. Overview of Studies Used to Calculate Proportions.

Study				Methodology			Age (Years)	Pathology				
Authors (Year)	Country	WHO Region	Income Level	Study Scale	Study Design	Limitations/Considerations	Range (Mean)	Sample Size	Low Back Pain (N)	DSD (N)	p(DSD | LBP)	Diagnosis Inclusion
Al-Saeed et al (2012)[50]	Kuwait	EMR	High	Hospital based	Prospective case-control	Consecutive patients with LBP referred to radiology department	16-29 (23.1)	214	214	12 106	0.056 0.495	SL SS
Albert et al (2011)[51]	Denmark	EUR	High	Hospital based	Retrospective	Outpatient spine clinic referred by primary care physician. Multiple pathologies per patient	≥10 (NR)	4233	4233	631 652 3628	0.149 0.154 0.857	SL SS DD
Anwar et al (2010)[52]	United States	AMR-US/Can	High	Hospital based	Prospective	Length of LBP was not mentioned	≥17 (53.1)	1299	1299	199	0.153	SL
Arnbak et al (2016)[53]	Denmark	EUR	High	Hospital based	Cross-sectional	Sample was randomly chosen from 5000 patients presenting with LBP	18-40 (NR)	5000	1037	801	0.772	DD
Gopalakrishnan et al (2015)[54]	India	SEAR	Lower Middle	Hospital based	Cross-sectional	Patients mostly referred by neurosurgery and orthopedic departments. Length of LBP was not mentioned	All (NR)	200	200	159	0.795	DD
Horvath et al (2010)[11]	Hungary	EUR	High	Population based	Cross-sectional	Random address sampling with questionnaire	16-67 (52.3)	9957	682	392 12	0.575 0.018	DSD SL
Kalichman et al (2010)[63]	United States	AMR-US/Can	High	Community based	Cross-sectional	Sample was taken from a heart study as part of an ancillary study	All (52.6)	187	150	68 6 6	0.453 0.040 0.040	DSD SL SS
Peterson et al (2000)[55]	United Kingdom	EUR	High	Hospital based	Cross-sectional	Consecutive patients from chiropractic clinic	18-91 (51.5)	NR	172	121	0.704	DD

Abbreviations: AFR, African Region; AMR-L, Region of the Americas (Latin America); AMR-US/Can, Region of the Americas (United States and Canada); DSD, degenerative spine disease, EMR, Eastern Mediterranean Region; EUR, European Region; LBP, low back pain; NR, not reported; p(DSD|LBP), probability of DSD in low back pain; SEAR, Southeast Asia Region; WHO, World Health Organization; WPR, Western Pacific Region.

Table 2. Incidence of Low Back Pain and Degenerative Spine Disease Worldwide by World Bank Income Group and WHO Region.

			Low Back Pain		Degenerative Spine Disease		
World Bank and WHO Population Description	Population	p(DSD∩LBP)	Incidence (per 100 000)	Persons Affected per Annum	Incidence (per 100 000)	Persons Affected per Annum	95% Confidence Interval
Income group							
Low	638 928 366	0.024	4576	29 239 633	2378	15 192 036	15 167 276 to 15 216 796
Middle[a]	5 521 156 908	0.034	6706	370 226 481	3484	192 358 573	191 765 641 to 192 951 505
High[a]	1 163 727 841	0.050	9682	112 675 005	5031	58 542 552	58 338 203 to 58 746 902
Global	7 323 813 115			512 141 119		266 093 161	265 465 515 to 266 720 808
Region							
AFR	990 267 592	0.024	4657	46 116 790	2420	23 960 900	23 919 924 to 24 001 877
AMR-L[a]	630 250 409	0.032	6217	39 181 292	3230	20 357 424	20 294 234 to 20 420 613
AMR-US/Can	357 270 594	0.050	8662	30 947 258	4501	16 079 267	15 937 891 to 16 220 642
EMR	648 060 427	0.029	5801	37 597 143	3014	19 534 348	19 480 722 to 19 587 973
EUR[a]	914 533 173	0.058	10 908	99 761 282	5668	51 832 969	51 635 828 to 52 030 111
SEAR	1 928 530 522	0.033	6865	132 394 480	3567	68 788 200	68 361 734 to 69 214 666
WPR[a]	1 849 874 735	0.032	6780	125 418 130	3523	65 163 498	64 782 904 to 65 544 091
Global	7 318 787 452			511 416 375		265 716 606	265 088 813 to 266 344 399

Abbreviations: AFR, African Region; AMR-L, Region of the Americas (Latin America); AMR-US/Can, Region of the Americas (United States and Canada); EMR, Eastern Mediterranean Region; EUR, European Region; p(DSD∩LBP), proportion of degenerative spine disease and low back pain; SEAR, Southeast Asia Region; WHO, World Health Organization; WPR, Western Pacific Region.

[a] Results calculated by average proportions.

surgically treatable disease.[56] In addition, there are nearly 5 billion people who lack access to basic surgical care,[57] a number that is much higher for those in need of neurosurgical care.[58] Neurosurgical diseases have significant impact on society, yet they have been largely ignored on the global stage.[59] The only neurosurgical procedure listed among the 44 essential surgical procedures in the Disease Control Priorities, third edition (Volume 1: Essential Surgery) is burr hole evacuation of subdural hematoma.[60] Access to neurosurgical care is limited by access to providers and cost-effective technology.[58] In an effort to address global neurosurgical needs, we must first attempt to characterize their global volume and epidemiology. It should be noted that primary and even secondary treatment of LBP, and the associated pathologies discussed, is nonoperative management, which may be lacking in LMICs. In these settings, especially, surgery is used for very select patients.

The estimates provided here are higher than those generated in previous efforts to quantify the volume of DSD worldwide. After carefully examining the results of an initial systematic review that included all reports of DSD, not just those associated with LBP, we formed a consensus that the data did not provide an accurate representation of the true volume of DSD. Although numerous studies were population based, many focused strictly on the aging population (65+ years old) and/or were of a small sample size. Also, a majority of the studies were from HICs (86%) and received a poor-quality rating. Because of these shortcomings in the collected studies, we modified our strategy and performed a second systematic review that reflects the current methodology. This method relied on incidence figures calculated from the IHME database, since reliable, population-based incidence figures for DSD in the majority of LMICs were unavailable in the literature. This provides greater confidence in the quality of the numbers from LMICs. The European incidence (5668 per 100 000) represents the highest volume of lumbar DSD. An important consideration is the presence of symptomatic DSD; however, a much larger percentage of the population has lumbar DSD, which may be clinically silent. The higher reported European incidence is also likely to be a product of large registries across European nations with high-level epidemiological data compared with the data available in LMICs. Similarly, the lower incidence in Africa is likely explained in part by lower quality data and lower access to diagnostic and treatment options for lumbar DSD from these area countries. An advantage to the methodology in this study is that the use of LBP as the denominator allows for assessment of symptomatic cases of DSD.

Since DSD is a broad term in the context of LBP, we chose to characterize spondylolisthesis (a common disease of the lumbar spine), disc degeneration, and spinal stenosis as subcategories to further delineate the types of pathology and the potential implications on surgical intervention. The estimated incidence of patients with spondylolisthesis in the setting of LBP was highest in Europe (832 per 100 000), with an estimated overall incidence worldwide of 0.20% (Table 3). Degenerative spondylolisthesis typically occurs in the setting of severe arthritis of the facet joints and intervertebral disk herniation. The use of spondylolisthesis in determining incidence of lumbar DSD may be limited by the potential inclusion of patients who have isthmic spondylolisthesis, which is not a degenerative condition, but is an osseous discontinuity of the vertebral arch at the isthmus—the pars interarticularis—and

Table 3. Comparison of Incidence for Total Degenerative Spine Disease and Specific Degenerative Spine Disease Conditions by World Bank Income Group and WHO Region.

World Bank and WHO Population Description	Population	Degenerative Spine Disease			Disc Degeneration			Spinal Stenosis			Spondylolisthesis		
		Incidence (per 100 000)	Persons Affected per Annum	95% Confidence Interval	Incidence (per 100 000)	Persons Affected per Annum	95% Confidence Interval	Incidence (per 100 000)	Persons Affected per Annum	95% Confidence Interval	Incidence (per 100 000)	Persons Affected per Annum	95% Confidence Interval
Income group													
Low	638 928 366	2,378	15 192 036	15 167 276 to 15 216 796	3602	23 013 638	22 986 682 to 23 040 594	919	5 872 195	5 853 811 to 5 890, 580	349	2 230 399	2 228 503 to 2 232 296
Middle[a]	5 521 156 908	3,484	192 358 573	191 765 641 to 192 951 505	5278	291 394 157	290 854 356 to 291 933 958	1347	74 352 584	73 894 242 to 74 810 927	512	28 240 876	28 193 667 to 28 288 085
High[a]	1 163 727 841	5,031	58 542 552	58 338 203 to 58 746 902	7621	88 683 116	88 497 879 to 88 868 354	1944	22 628 521	22 470 424 to 22 786 618	739	8 594 849	8 578 566 to 8 611 133
Global	7 323 813 115		266 093 161	265 465 515 to 266 720 808		403 090 911	402 519 575 to 403 662 246		102 853 301	102 368 110 to 103 338 492		39 066 125	39 016 150 to 39 116 099
Region													
AFR	990 267 592	2420	23 960 900	23 919 924 to 24 001 877	3665	36 297 142	36 257 817 to 36 336 466	935	9 261 635	9 230 278 to 9 292 992	355	3 517 789	3 514 558 to 3 521 020
AMR-L*	630 250 409	3230	20 357 424	20 294 234 to 20 420 613	4893	30 838 419	30 779 850 to 30 896 988	1249	7 868 779	7 820 093 to 7 917 464	474	2 988 749	2 983 734 to 2 993 764
AMR-US/Can	357 270 594	4501	16 079 267	15 937 891 to 16 220 642	6818	24 357 658	24 237 169 to 24 478 147	1740	6 215 138	6 104 645 to 6 325 631	661	2 360 657	2 349 281 to 2 372 033
EMR	648 060 427	3014	19 534 348	19 480 722 to 19 587 973	4566	29 591 583	29 540 384 to 29 642 783	1165	7 550 634	7 509 555 to 7 591 714	443	2 867 910	2 863 677 to 2 872 143
EUR[a]	914 533 173	5668	51 832 969	51 635 828 to 52 030 111	8586	78 519 112	78 331 258 to 78 706 967	2191	20 035 058	19 883 981 to 20 186 136	832	7 609 791	7 594 225 to 7 625 357
SEAR	1 928 530 522	3567	68 788 200	68 361 734 to 69 214 666	5403	104 203 724	103 819 958 to 104 587 489	1379	26 588 784	26 258 441 to 26 919 126	524	10 099 051	10 065 029 to 10 133 073
WPR[a]	1 849 874 735	3523	65 163 498	64 782 904 to 65 544 091	5336	98 712 847	98 363 682 to 99 062 012	1362	25 187 723	24 893 931 to 25 481 515	517	9 566 895	9 536 633 to 9 597 157
Global	7 318 787 452		265 716 606	265 088 813 to 266 344 399		402 520 486	401 948 999 to 403 091 973		102 707 751	102 222 452 to 103 193 049		39 010 841	38 960 856 to 39 060 826
p(DX|LBP)			0.520			0.787			0.076			0.201	

Abbreviations: AFR, African Region; AMR-L, Region of the Americas (Latin America); AMR-US/Can, Region of the Americas (United States and Canada); EMR, Eastern Mediterranean Region; EUR, European Region; p(DX|LBP), probability of a specific spine disease in low back pain; SEAR, Southeast Asia Region; WHO, World Health Organization; WPR, Western Pacific Region.

[a] Results calculated by average proportions.

may occur in young adults, typically athletes, as a consequence of bilateral pars interarticularis stress fractures.[61,62]

The finding that the incidence of disc degeneration (0.787) exceeds the overall incidence of lumbar DSD (0.520), at first glance, appears to be a contradiction but reflects the methodology of the review. The lumbar DSD papers reviewed[11,63] did not include disc degeneration as a subcategory. The varying inclusion and correspondence of subpathologies yielded varying proportions, thus contributing to the greater volume of disc degeneration compared with lumbar DSD. One could use disc degeneration as the denominator for this study; however, we decided that using LBP is a more methodologically sound method in further evaluating spondylolisthesis and spinal stenosis because these patients often present with back pain and may or may not have evidence of disc degeneration on imaging. It is worth noting that many cases of lumbar spine disease are often associated with lower extremity pain rather than low back pain; however, even fewer studies exist with proven findings of degeneration for the lower extremities. Thus, the decision was made to use LBP as the denominator.

The highest estimated incidence of spinal stenosis was seen in Europe (2191 per 100 000) with the lowest in Africa (935 per 100 000). Symptomatic degenerative lumbar spinal stenosis with clinical neurogenic claudication is a frequent source for spinal surgery consultation, which most commonly occurs beyond the fifth decade of life. It has been postulated that more than 2.4 million people in the United States alone will be affected by symptomatic lumbar spinal stenosis by the year 2021.[64]

Our goal in undertaking this meta-analysis was to generate preliminary data to prompt further study into the epidemiology of degenerative lumbar spine disease with LBP as it might apply to surgical intervention (eg, surgeon availability, access to advanced care). Similarly, additional studies should be undertaken to examine the burden of cervical degenerative disease, degenerative scoliosis, spinal cord injury, spinal infection, and rheumatological diseases that affect the spine to obtain a more complete picture of the global burden of these diseases. The tremendous amount of data found within the literature cannot possibly be summarized in a single study, but the results are necessary if we are to begin to plan a global public health effort.

Limitations

Although this was a comprehensive, systematic review of the literature, there are shortcomings based on the quality of the evidence available for review. The literature reviews and meta-analyses conducted to obtain DSD and LBP relative ratios rely on studies with heterogeneous and often biased study designs. A topic this general inherently is reported in populations that are nonuniform, making direct comparisons challenging. Combining epidemiologic data across heterogeneous cohorts risks misrepresentation of disease volume.

As demonstrated by the methodology, there is a paucity of epidemiological information from LMICs, thus likely under-representing these areas in the overall volume of DSD and LBP. In addition, a large amount of the literature is focused on elderly, aging populations—this likely stems from the notion that degeneration implies an age relation, which is a misnomer that is highly prevalent in the literature.

An additional consideration is that the nomenclature used in the literature limited the number and quality of the studies analyzed. DSD can include loss of disc height, traction spurs, and annular osteophytes.[51] There are many publications with the term degenerative disc disease in the title, but this term does not have an explicit definition.[46] Degenerative disease of the spine (spondylosis) is defined as the finding of decreased disc height and fragmentation on magnetic resonance imaging.[51] Additionally, radiological diagnostics differed between studies. Although interrater reliability testing and specific protocols were used for diagnostic validity, the variability in imaging modality across studies may produce limitations. The differing, and arbitrary, use of terms may preclude adequate comparison with other studies in a review such as this. Stricter definitions could be used to improve global estimates of disease in the future.

Although the methodology used within this model has limitations, it has been previously used in similar studies to estimate national and global incidence rates of head injury, femoral fractures, and traumatic brain injury.[65-67] Furthermore, its use can be justified through the use of sound scientific estimation because it is necessary to produce data for countries where research is limited, unreliable, or entirely unavailable. Our goal to estimate the volume of DSD on a global scale has been achieved—albeit with the aforementioned considerations. We estimated the volume of DSD with regional and income-level information. An important factor to the epidemiology and reporting of DSD in the setting of LBP may be from cultural bias and reporting. Back pain in western cultures is more prevalent because pain thresholds seem to be lower.[68] Secondary gain, which is more prevalent in HIC and Western culture, may also play a role; these 2 factors may affect reporting, and this represents a limitation of the study.

The results of our data must be considered within the context of the study. First, incidence values for LBP were obtained through the GBD data, which are modelled estimates. Also, only symptomatic cases were taken into account; DSD does not always present with LBP. For this reason, our results could be viewed as a minimum approximation. The studies that were used to calculate proportions may also present limitations, despite being the highest quality available within our search. First, studies used in our meta-analysis were weighted heavily on hospital-based studies, which was necessary in creating proportions. Second, our review excluded non-English literature, which may have provided more data from LMIC regions where literature was scarce and given a more accurate picture. Therefore, these estimates of DSD should be cautiously applied to the general global population. By nature of the available data from the literature, we assumed uniform disease susceptibility across age groups and sexes. We also assumed member

countries of a particular WHO region or WB income group share the same injury incidence.

Ideally, to overcome the limitations presented in this study and increase the accuracy of a global estimation, a series of large, population-based studies will need to be performed and represent every type of population worldwide. It is important to acknowledge the value of these studies and the data they would produce, despite the vast cost and limited feasibility of such a project. Future studies would also benefit from an expert panel defining the criteria for spinal degeneration. Nevertheless, we believe that these estimations serve as a starting point in determining the global volume of spinal disease as it relates to neurosurgical awareness.

Conclusions

In our global model, the annual incidence of adult DSD is roughly estimated at 266 million individuals. Per capita, the highest annual incidence of DSD and back pain is estimated in Europe and North America (5668 and 4501 per 100 000 people, respectively); however, taking into account regional populations, the greatest volume of DSD is in Southeast Asia (69 million) and the Western Pacific (65 million). Thus, the health care systems in LMICs would encounter nearly 4 times as much total DSD as those in HICs. These estimates are limited by relatively low-quality data from LMICs and suggest the need for more robust and accurate reporting with uniform use of terminology. Uniform definitions of degenerative spine conditions requiring surgical intervention (such as ICD9 or ICD10 codes) will improve the efforts to characterize the global burden of disease and its impact on quality of life. A global effort to address degenerative conditions of the spine in regions with the greatest demand is imperative to decrease overall disparity and to decrease disease incidence and morbidity.

Appendix

PubMed Search Terms (January 2016)

((low back pain[tiab] OR neck pain[tiab]) OR ((low back[tiab] AND neck[tiab]) AND pain[tiab])) AND ("Intervertebral Disc Degeneration"[Mesh] OR "osteoarthritis, spine"[Mesh] OR "Spinal Stenosis"[Mesh] OR "Spondylosis"[Mesh] OR "Spondylolisthesis"[Mesh] OR "Intervertebral Disc Degeneration"[tiab] OR "Spinal Stenosis"[tiab] OR "Spondylosis"[tiab] OR degeneration[tiab] OR degenerative[tiab] OR "Spondylolisthesis"[tiab] OR "listhesis"[tiab] OR "disc degeneration"[tiab] OR "degenerative disc disease"[tiab] OR "spinal osteoarthritis"[tiab] OR "degenerative spine"[tiab] OR "spinal degeneration"[tiab] OR "spine degeneration"[tiab] OR "spine osteoarthritis"[tiab] OR "spine stenosis"[tiab] OR "foraminal stenosis"[tiab] OR "degenerative scoliosis"[tiab]) NOT ("animals"[Mesh] NOT "humans"[Mesh]) AND hasabstract [text] AND ("1990/01/01"[PDAT]: "3000/12/31"[PDAT]) AND English[lang]

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