



# The Global Spine Care Initiative: public health and prevention interventions for common spine disorders in low- and middle-income communities

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## Abstract

**Purpose** The purpose of this study was to develop recommendations for prevention interventions for spinal disorders that could be delivered globally, but especially in underserved areas and in low- and middle-income countries.

**Methods** We extracted risk factors, associations, and comorbidities of common spinal disorders (e.g., back and neck pain, spinal trauma, infection, developmental disorders) from a scoping review of meta-analyses and systematic reviews of clinical trials, cohort studies, case control studies, and cross-sectional studies. Categories were informed by the Global Spine Care Initiative (GSCI) classification system using the biopsychosocial model. Risk factors were clustered and mapped visually. Potential prevention interventions for individuals and communities were identified.

**Results** Forty-one risk factors, 51 associations, and 39 comorbidities were extracted; some were associated with more than one disorder. Interventions were at primary, secondary, tertiary, and quaternary prevention levels. Public health-related actions included screening for osteopenia, avoiding exposure to certain substances associated with spinal disorders, insuring adequate dietary intake for vitamins and minerals, smoking cessation, weight management, injury prevention, adequate physical activity, and avoiding harmful clinical practices (e.g., over-medicalization).

**Conclusion** Prevention principles and health promotion strategies were identified that were incorporated in the GSCI care pathway. Interventions should encourage healthy behaviors of individuals and promote public health interventions that are most likely to optimize physical and psychosocial health targeting the unique characteristics of each community. Prevention interventions that are implemented in medically underserved areas should be based upon best evidence, resource availability, and selected through group decision-making processes by individuals and the community.

**Graphical abstract** These slides can be retrieved under Electronic Supplementary Material.

The graphical abstract consists of three slides from a presentation. The first slide, titled 'Key points', lists three main findings: 1. Recommendations for spine-related disorders based on risk factors, comorbidities, and associations. 2. Recommendations developed by a multi-disciplinary team. 3. Recommendations placed in the context of local resources and priorities. The second slide, titled 'Risk factors, associations, and comorbidities for spinal conditions', shows a 2x2 grid of biopsychosocial variables: Non-modifiable (Age, sex, heredity, etc.), Biological (High BMI, low physical activity, etc.), Exposure (Trauma, smoking, etc.), and Psychosocial (Education level, high job demands, etc.). The third slide, titled 'Take Home Messages', lists three key messages: 1. Prevention principles and health promotion strategies are incorporated in the GSCI care pathway. 2. Interventions should encourage healthy behaviors. 3. Prevention interventions should be based on best evidence, resource availability, and selected through group decision-making processes.

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Extended author information available on the last page of the article

**Keywords** Health promotion · Spinal diseases · Risk factors · Epidemiology

## Introduction

Spinal disorders are a significant cause of morbidity and suffering [1]. Specific and non-specific disorders affecting the spine contribute substantially to global prevalence, overall burden, and global years lived with disability [2]. Common spinal disorders affect people of all ages and socioeconomic status but are especially burdensome to underserved and low-income communities [3, 4].

Vulnerability to spinal disorders, and their associated comorbidities, is often greater in low- and middle-income countries than those with greater resources [5, 6]. In low- and middle-income countries, back pain may be more common [7], spinal cord injuries have worse outcomes and reduced life expectancy [8, 9], and spinal tuberculosis has greater prevalence and worse clinical outcomes [10]. Further, the treatment of spinal disorders and their associated disability is costly. In high-income countries, the presence of a spinal disorder in an individual is associated with nearly double the medical costs than in those individuals without a spine problem [11]. Spine care is also expensive in low- and middle-income countries, and effective therapies in such areas are not well studied [12]. Thus, recommendations have been made for health systems leaders in low- and middle-income countries to investigate prevention measures that could be considered with limited economic resources for overall health care [13, 14]. If methods can be identified to prevent initial occurrence or minimize the progression of these conditions, underserved communities might more effectively reduce the burden of spinal disorders [1, 12, 15], including associated morbidity and mortality [16].

Sociodemographic variables and modifiable risk factors, addressed within cultural contexts, have the potential to affect the burden of spinal disorders [15, 16]. Spinal disorders are not isolated and present in people who have other health concerns and whose specific environmental, occupational, and recreational exposures put them at risk. It is therefore essential that these common risk factors, associations, and comorbidities that may influence the prognosis and type of intervention be included in a spinal care pathway.

Risk factors have informed care pathways for other non-communicable diseases, such as cardiovascular disease and postoperative complications [17, 18]. As has been done with these other diseases, it is reasonable to consider similar strategies for spine conditions based on modifiable factors that can be addressed through prevention at both the individual and community levels. However, we are unaware of this approach for spine care because there is little research evaluating prevention campaigns for spinal disorders. A guiding principle of the Global Spine Care Initiative (GSCI) is “to

develop models for prevention and care that could reasonably be instituted in communities with different levels of healthcare resources” [19].

The purpose of this study was to develop recommendations for prevention interventions for spinal disorders that could be delivered globally, but especially in underserved areas and in low- and middle-income countries. Recommendations for prevention interventions were developed for the GSCI spine care pathway and model of care to address common spinal disorders [20–23].

## Methods

In a prior study, we performed a scoping review of variables, such as risk factors, epidemiological associations, and comorbidities of common spinal conditions [24]. The scoping review followed PRISMA guidelines and met the criteria for scoping reviews, including: (1) identifying the research question; (2) identifying relevant studies; (3) using an iterative team approach to study selection and data extraction; (4) charting the data using quantitative and qualitative analysis; and (5) summarizing the results to include implications for policy, practice, or research [25].

Because there was no globally recognized single system of taxonomy for spinal disorders, case definitions were developed to identify search terms and perform the scoping review, which resulted in three groups: [24].

- Spinal pain of unknown origin—Group 1: Spinal disorders with history and examination findings that do not lead to a specific clinical diagnosis and have no diagnostic imaging, laboratory, or neurodiagnostic findings [26].
- Spinal syndromes—Group 2: Spinal disorders with history and examination findings that lead to a clinical diagnosis [27–29].
- Spinal pathology—Group 3: Spinal disorders with history and examination findings that lead to a clinical diagnosis that can be confirmed by diagnostic imaging, laboratory, or neurodiagnostic findings [29].

The scoping review focused on risk factors, associations, and comorbidities of common spinal disorders that are likely to be seen in ambulatory care clinics globally. Risk or prognostic factors were any attribute, characteristic or exposure of an individual that increased the likelihood of developing an incident common spinal disorder, morbidity or mortality as a result of that disorder [30, 31]. These data relied on the results of clinical trials, cohort studies, case control studies, or reviews of these studies. Although risk factors

are not always involved in the disease process, sometimes they have predictive value regarding possible causes of the disease [32]. They help to inform research and data collection from populations to observe and, ideally, prevent disease occurrence. Epidemiological associations were behaviors, traits, or exposures associated with the disorder but for which there was not strong evidence to warrant calling them risk factors. Associations were gathered from reviews of cross-sectional studies recognizing that these associations could not be considered risk factors since outcome variables were not assessed before and after exposure. Associations included non-modifiable variables, exposures, or modifiable variables, but not other diseases. Comorbidities were defined as diseases or conditions associated with the spinal disorder being studied without assigning any condition as an index condition [33]. After addressing inclusion and exclusion criteria, 143 studies were included in the final scoping review. For each study reviewed, the risk factors for every spinal disorder studied (and the related measures of association) were reported in a standardized data extraction spreadsheet. Epidemiological associations and comorbidities were reported using the same method. For each group of spinal disorders, the standardized spreadsheet was further divided by each specific disorder, resulting in eight lengthy and in-depth spreadsheets [24].

For the current paper, one investigator (CDJ) collapsed the detailed data from the scoping review into summarized risk factors, associations, and comorbidities per spinal disorder. These were further organized into a spreadsheet with categories of modifiable and non-modifiable variables, when possible. The lead investigator (BNG) verified the process. Any disagreements were resolved through discussion. Inclusion of potential management considerations for healthcare providers who are in the position to discuss the prevention of specific spinal disorders with patients was added to the spreadsheet, per variable.

From this spreadsheet, the risk factors, associations, and comorbidities were aggregated and sorted into 1 of 4 categories. The categories were those that represent the biopsychosocial theoretical model providing the foundation for the scoping review and the current paper. These categories (biological, psychosocial, non-modifiable, exposures) and the variables in the categories were mapped visually to gain a sense of how they might overlap and how they could be considered in a spine care program.

Based upon the summarized risk factors, associations, and comorbidities and the mapping of variables described in the steps above, preventive clinical actions that might be considered in a spine care program were then linked by the first three authors (BNG, CDJ, SH) to the GSCI classification system [20]. The GSCI classification system includes prevention assessment, provider-directed prevention interventions, and self-care prevention interventions. Prevention

assessment includes those clinical activities that help to identify potential risk factors or comorbidities during the evaluation of a patient. Provider-directed prevention interventions are those that healthcare providers may initiate in the clinical encounter. Self-care interventions are those prevention steps that patients and their caregivers may take when considering primary, secondary, or tertiary prevention. Thus, these types of clinical actions were used for the linking of the summarized data to the GSCI classification system. The conventional levels of prevention were used in this process, defined as follows:

- Primary prevention aims to prevent disease or injury before it ever occurs. For example, encouraging seatbelt use for individuals and communities to prevent motorized vehicle injuries is primary prevention strategies.
- Secondary prevention aims to prevent worsening of a condition that has already occurred. For example, screening for fall risk in those with osteoporosis is a secondary prevention strategy that can be used for both individuals and communities.
- Tertiary prevention aims to reduce the disability of an ongoing condition that has lasting effects [31]. Tertiary prevention attempts to prevent a condition from worsening and may focus on fortifying what function remains. Preventing the onset of comorbidities associated with spinal cord injury is an example of tertiary prevention.
- Quaternary prevention aims to prevent the medicalization or over-medicalization of health concerns [34]. Quaternary prevention might include the prevention of patient dependence on care or avoiding the use of opioids for chronic non-cancer pain.

Following the summarization and mapping of the aggregated data, the authoring team reviewed the materials for accuracy and relevance to their area of content expertise. Each member submitted recommendations for revision to the primary author, which were integrated into a revised draft and redistributed to the team. This iterative process continued until consensus was reached by the team.

## Results

Twelve spinal disorders were included in the scoping review [24]. There were 41 risk factors, 51 associations, and 39 comorbidities related to spinal disorders; some of these were linked with more than one spinal disorder [24]. Table 1 shows risk factors, associations, comorbidities, considerations in patient care and provides patient management considerations for healthcare providers who are in the position to modify or act on factors related to prevention for each specific spinal disorder [35–41]. The suggestions represent

**Table 1** Risk factors, associations, and comorbidities for the spinal disorders reviewed and patient management considerations for healthcare providers who are in the position to act on factors related to prevention of specific spinal disorders

Group 1—Spinal pain of unknown origin	Risk Factors	Associations	Comorbidities	Considerations in patient care
Neck pain	Modifiable High job demands Highly monotonous work	Modifiable High gravitational forces (pilots) Psychological status Low levels of support at work Prolonged sitting/sedentary work posture Poor health No or low physical activity Smoking Non-modifiable Prior history of neck, low back, or other musculoskeletal pain Female	Overall ill health Pain in other body sites	Ask questions about Job requirements and environment Psychological status Prior history of other musculoskeletal problems Physical activity Smoking habits Perform Review of systems to assess overall health
Thoracic pain	Modifiable Poor mental health Non-modifiable Older (vs younger) adolescent	Modifiable Postural changes associated with backpack use (children) Backpack weight Difficulty with activities of daily living (in adults) Non-modifiable Female sex (in children) Later age of puberty	Other musculoskeletal symptoms Mental health concerns	Ask questions about: Back pack wearing habits/weight (children) Perform: Review of systems to include overall musculoskeletal health and mental health
Low back pain	Modifiable Smoking Obesity Negative expectations about recovery (for chronicity) High job demands Low social support Low supervisor support Low job satisfaction Depressive symptoms	Modifiable Whole body vibration Overweight and obesity (children) Low job satisfaction Work-related manual materials handling Frequent bending and twisting Non-modifiable Increasing age	Psychiatric conditions Diabetes Headache Osteoarthritis Osteoporosis Chronic fatigue syndrome Fibromyalgia Cardiovascular conditions Sciatica Pain at other body sites Other musculoskeletal injuries	Ask questions about: Smoking behaviors and offer options for tobacco cessation Job requirements and environment Perform: Body mass index assessment and offer advice for patients with values > 25 If negative expectations or several psychosocial concerns, consider sorting for care Screen with STarT Back tool (35) Screen for depression (Beck Depression Inventory) Review of systems to include overall musculoskeletal health and mental health Screen for type two diabetes in patients with sustained blood pressure (either treated or untreated) > 135/80 mm Hg (36)

**Table 1** (continued)

Group 2—Spinal syndromes	Risk Factors	Associations	Comorbidities	Considerations in patient care
Radicular pain (sciatica)	Modifiable Obesity Overweight Current smoking Manual labor	Modifiable Whole body vibration Markers for inflammation	N/A	Ask questions about: Smoking behaviors and offer options for tobacco cessation Job requirements and environment Perform: Body mass index assessment and offer advice for patients with values > 25
Whiplash associated disorders (poor recovery)	Modifiable Neck disability Index score > 15 High initial pain intensity Catastrophizing	Modifiable Overweight and obesity Smoking High levels of physical activity High serum c-reactive protein levels	Psychological disorders Back pain Headache Widespread chronic pain Degeneration Radicular symptoms Cranial nerve or brainstem disturbance Dizziness, dysphagia, fatigue Pregnancy	Ask questions about: Assess pain severity Perform: Neck Disability Index (37) Review of systems to include overall musculoskeletal health and mental health Cranial nerve examination
Pelvic girdle pain	N/A	N/A	N/A	N/A
Group 3—Spinal pathology	Risk factors and associations	Associations	Comorbidities	Considerations in patient care
Arthritic spinal disorders	Modifiable Smoking Worker's compensation claim Non-modifiable Degenerative scoliosis	Modifiable Overweight and obesity Whole body vibration Smoking Disk infection Non-modifiable Male (for cervical) Narrow disk space and spondylolysis-thesis Polymorphisms of vitamin d receptors (protective)	N/A	Ask questions about: Smoking behaviors and offer options for tobacco cessation Workers' compensation Job requirements and environment Perform: Body mass index assessment and offer advice for patients with values > 25
Spinal cord injury—traumatic	Non-modifiable Male sex Age 20–29 and > 70 year	Modifiable Motor vehicle accidents Falls Violence Sports injuries	Depression and depressive symptoms Anxiety Post-traumatic stress disorder High levels or chronic pain Ankylosing spondylitis Osteoarthritis Peripheral neuropathy Metabolic disorders Other diseases (cardiovascular, pulmonary, gastrointestinal) Other pathology (renal, cerebral) Neoplasia	Perform: Encourage use of seat belts Reinforce importance of safety equipment to prevent falls at work Use fall risk assessment tool (38) if patient is hospitalized Encourage use of proper protective equipment in sport Screen for comorbidities. Consider beck depression and anxiety inventories Review of systems

**Table 1** (continued)

Group 3—Spinal pathology	Risk factors and associations	Associations	Comorbidities	Considerations in patient care
Spinal cord injury—non-traumatic	Non-modifiable Advancing age (> 75 year)	N/A	Tumors Degeneration Vascular problems	N/A
Spinal tuberculosis	Non-modifiable Age > 35 year History of imprisonment Male sex Previous tuberculosis infection Genetic polymorphisms of monocyte chemotactic protein-1	N/A	N/A	N/A
Spinal tuberculosis (poor outcomes)	Modifiable Delayed diagnosis Non-modifiable Severe vertebral collapse Age < 7 year at the time of diagnosis Involvement at the thoracolumbar level Loss of > 2 vertebral bodies At-risk signs on radiography	N/A	Chronic renal failure Diabetes mellitus HIV infection	Perform: Assessment for at-risk radiographic signs in individuals with spinal tuberculosis
Metabolic—vertebral fracture associated with osteoporosis/osteopenia	Modifiable Use of selective serotonin reuptake inhibitors Use of antidepressants (in older people) Use of proton pump inhibitors Current smoking Untreated hyperprolactinemia Non-modifiable Diabetes	Modifiable Education (protective) Non-modifiable Heritability Small vertebral body dimensions Adiponectin negatively associated with bone density	Low bone mineral density Frailty	Ask questions about: Selective serotonin reuptake inhibitors, antidepressants, and proton pump inhibitors Tobacco habits, offer smoking cessation Perform: Screen for diabetes Screen for osteoporosis (39) Assess for hyperprolactinemia
Congenital or developmental—Spina bifida	Modifiable Deficient folic acid consumption Maternal use of antiepileptic medications (carbamazepine, valproic acid) Maternal ingestion of chlorine by-products in drinking water First-trimester maternal influenza Maternal obesity	N/A	N/A	Perform recommend folic acid supplementation Reconcile medication list, switch mother to alternative antiepileptic medication (40) Find out from local water authorities the level of chlorine in drinking water and whether the level is ≤ the threshold recommended by WHO. (41) Encourage hand washing and avoidance of contact with sick persons Monitor maternal weight gain and implement nutritional and activity interventions if necessary

**Table 1** (continued)

Group 3—Spinal pathology	Risk factors and associations	Associations	Comorbidities	Considerations in patient care
Congenital or developmental—Scoliosis curve progression	N/A	Non-modifiable High initial Cobb angle Thoracic curve Age < 13 year at time of diagnosis Pre-menarche at diagnosis	Osteopenia	N/A

N/A not applicable

potential options for healthcare providers to consider while also factoring in relative access to resources. Most of the clinical suggestions provided have minimal or no cost (e.g., education about behavior modification, nutrition).

The biopsychosocial model of health integrates biological, psychological, and social components of health and is a useful framework to address risk factors, associations, comorbidities, and potential prevention of spinal disorders. Individuals experience spinal disorders in combination with other health concerns within the biopsychosocial context. Coexistence of two or more conditions is common and associated with increased utilization of health care and reduced quality of life and functional status [42]. Figure 1 is a visual representation of the aggregated risk factors, associations, and comorbidities within the domains of biological variables, psychosocial inputs, non-modifiable variables, and exposures. By definition, there are no non-modifiable factors present in the comorbidity category. The degree to which these domains may overlap or influence each other is unknown, but interactions between these domains were mentioned frequently in the studies reviewed.

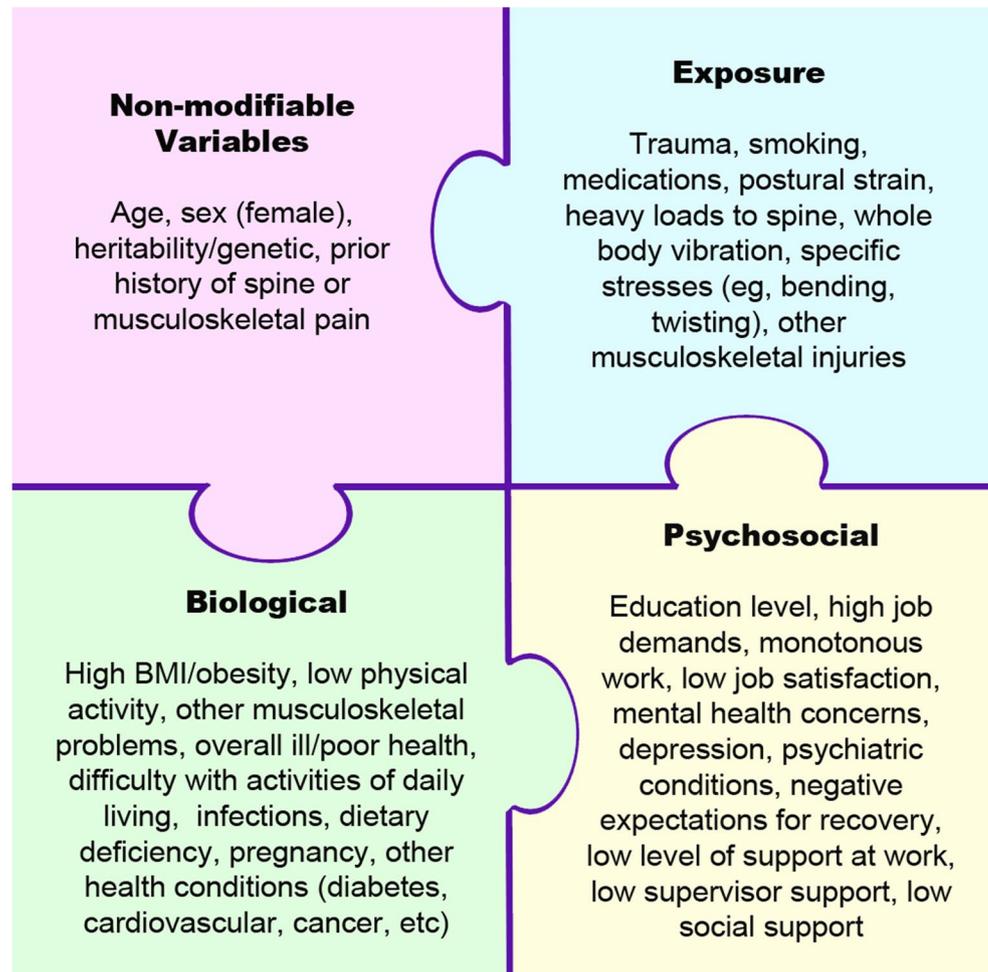
The GCSI classification system has five classes, ranging from no overt spinal disorder or symptoms (class 0) to life-threatening severe or systemic pathology (class V) [20]. Table 2 shows the prevention assessments, provider-directed prevention interventions, and self-care prevention interventions that can be considered within the GCSI classification system and care pathway for spinal disorders. These prevention recommendations address the 12 spinal disorders studied and range from preventing first occurrence to minimizing the long-term effects of a disorder. While the GCSI classification system and care pathway are focused on care for individuals, some of the prevention concepts are applicable to communities where prevention and public health education are needed.

## Discussion

We believe that this paper is the first of its kind to provide recommendations for a spine care pathway regarding individual and community prevention strategies based upon potential risk factors, comorbidities, and associations. This set of recommendations comes from an interprofessional and international team of authors and lists activities that can be addressed by patients, communities, and clinicians in underserved and low- and middle-income countries. It places the prevention of spinal disorders within the context of local resources, needs, and priorities and encourages latitude in offering prevention at both individual and community levels.

Our recommendations were developed based on information from the previous scoping review that created a compendium of risk factors, associations, and comorbidities

**Fig. 1** Risk factors, associations, and comorbidities for spinal conditions clustered by category. These are areas that should be considered to include in spine care programs



for common spinal disorders commonly seen in ambulatory clinics [24]. The research in the paper on which this paper is based focused mainly on variables associated with individual disorders. However, the present study provides a unique vantage point in looking at the multiple risk factors, associations, and comorbidities common to many spinal disorders. Spinal disorders are complex and occur in people who have other health concerns, health behaviors, and environmental, recreational, and occupational exposures. It is therefore essential that a clinical care pathway for ubiquitous spinal disorders consider multiple inputs for prevention, rather than a mono-causal fashion. Several variables, such as obesity, smoking, nutritional concerns, mental health, and work environment, were related to multiple spinal disorders. For instance, people with spine pain may have other comorbidities and associated factors that affect their spinal disorder experience and disability. Accordingly, these variables are reasonable targets for spinal disorder prevention efforts.

Common spinal disorders present specific opportunities for prevention on the individual patient and population level. Since several interventions are useful for more than one disorder, we recommend selecting between interventions based

on the likelihood to be used by clinicians and the existence of supporting evidence. For a clinician to address an individual's needs, prevention interventions may be incorporated throughout different parts of the clinical encounter. Components of the history and assessment can include information about both modifiable and non-modifiable risk factors and screening questions (e.g., World Health Organization's FRAX Fracture Risk Assessment Tool). Selected diagnostic procedures (e.g., dual energy x-ray absorptiometry) may help identify other important variables [43]. Based upon this information, prevention strategies target primary, secondary, tertiary, and/or quaternary levels depending upon the stage and needs of the person. For example, an intake form may identify an older female with thoracic pain and family history of osteoporosis as someone who may be at risk for osteoporotic fracture. An assessment may include a fracture risk assessment, postural analysis, diagnostic imaging, or bone density scan, which could confirm the level of osteopenia. In such a case, assessment and interventions focus on treating the pain and osteoporosis; however, the secondary prevention recommendations would aim to prevent further fracture and deformity. Thus, prevention aims are integrated

**Table 2** Prevention assessments, provider-directed prevention interventions, and self-care prevention interventions. Recommendations are based on specific needs, preferences, and available resources of the individual and community

For individual persons (classes 0–IV) <sup>a</sup>	Provider-directed prevention intervention (healthcare worker provides education and recommendations)	Self-care prevention interventions (person and caregivers participate in prevention strategies)
Assessment	Modification of prevention interventions due to sex and age for some spine conditions	Modification of self-care prevention interventions due to sex and age for some spine conditions
Sex and age (non-modifiable risk factors that may be important in prevention assessment for some spine conditions)	Provide education at appropriate level of understanding	Self-care activities are at appropriate level of understanding
Level of education	If smoker, offer options for smoking cessation	Engage in activities or programs to stop smoking
Smoking habits	Provide education on factors or provide/refer for appropriate clinical interventions as secondary/tertiary prevention intervention	Use available educational materials or community resources for management of conditions related to spinal disorders
Other related health conditions (e.g., other musculoskeletal conditions, diabetes, cardiovascular conditions)	Provide advice on unintentional injury, fall, and occupational injury prevention	Use occupational, sports, and motor vehicle safety and personal protective devices; implement home fall prevention strategies
Risk for unintentional injuries or falls or physical occupational factors (e.g., type of work, posture)	Assess for at-risk spinal radiographic signs in individuals with spinal tuberculosis; reconcile medication list	Use available educational materials or community resources for preventing exposure to tuberculosis or risk factors for spinal tuberculosis and for side effects/interactions of medications
Other exposures (e.g., infections, medications) <sup>b</sup>	Provide education on factors or provide/refer for appropriate clinical psychosocial support as secondary/tertiary prevention intervention	Receive psychological and/or social support and activities
Mental health (e.g., depression), psychosocial job-related factors (e.g., monotonous work, levels of support), and negative expectations of care	Provide physical activity recommendations; monitor weight gain in pregnant females	Follow physical activity recommendations and monitor weight
Level of physical activity and body mass index	Provide advice for weight management, adequate dietary consumption of vitamin D and calcium	Engage in osteoporosis and related vertebral fracture prevention and management
Dietary habits for weight management and vitamin D and calcium for osteoporosis	Provide advice on adequate intake of folic acid, avoiding exposures to drugs, chemicals, infection; hand washing for women of child bearing age as secondary/tertiary prevention intervention <sup>c</sup>	Avoid risk factors for fetal development of spinal disorders during pregnancy
Dietary folic acid consumption and exposures to influenza, chlorine by-products, carbamazepine and valproic acid in pregnant women <sup>f</sup>	Avoid dissemination of inaccurate information. Avoid use or promotion of harmful procedures. Prevent medicalization of conditions when appropriate. Avoid over-treatment during care <sup>d</sup>	Not applicable
Do not screen for conditions where screening lacks evidence <sup>d</sup>		
For communities	Directed prevention interventions (healthcare worker provides education and recommendations)	Prevention interventions (community participates in prevention strategies)
Assessment	Prevent medicalization or over-medicalization of health concerns in community education and communication materials <sup>d</sup>	Primary prevention interventions: community educational programs for preventing locally prevalent spinal disorders Secondary and tertiary prevention interventions: community education programs for preventing locally prevalent spinal disorders or decreasing community burden of existing prevalent disorders
Primary prevention assessment for communities could include obtaining information from screening, surveys, or available reports to identify risk factors, associations, and comorbidities to help prevent spinal disorders before they develop		
Do not screen for conditions where screening lacks evidence <sup>d</sup>		

<sup>a</sup>Assumes severe spinal disorders (class V of GSCI Care Pathway) will be managed at a tertiary care facility

<sup>b</sup>For people at risk for tuberculosis, primary prevention assessment includes a tuberculosis laboratory test

<sup>c</sup>Assessments and interventions for pregnant women are not applicable in tertiary prevention

<sup>d</sup>Represents quaternary prevention

and work in conjunction with treatment of the condition and the other components of the care pathway.

Some concepts used in community health programs for communicable diseases may be applicable to prevention of spinal disorders. Communities have the potential to change the physical, economic, and social environment over time to facilitate a better level of health among individuals [44]. Population-based prevention strategies, such as policy and educational programs, could be integrated into existing healthcare systems and supported by various agencies (e.g., WHO). Collaboration with existing healthcare infrastructures to implement prevention programs could be considered when developing local spine care programs. Aligning public health and intervention strategies with local needs is important and may help to reduce disability, morbidity and mortality associated with the spinal disorders studied.

Each community has different needs for spine health care. Some may have a higher incidence of spinal injuries, depending upon traffic laws and work conditions, whereas others may be more prone to infection or spinal deformities. Thus, epidemiologic analysis of spinal disorders on a local level should provide the information needed to prioritize prevention programs for a specific community. Factors that may influence decisions regarding priorities may include: access, cost, ability to implement on a community, and/or individual level, risk for harm/safety. Healthcare providers and public health personnel who desire to prevent spinal disorders or reduce their associated disability may consider selecting health behaviors, exposures, and comorbidities that are common to the most problematic conditions in the community. Once the variables have been identified, a prevention program can be considered that addresses these factors. Provided are examples of how spinal conditions could be addressed at the individual and/or community level and for the various stages of prevention. We chose three conditions for the examples, including osteoporotic spinal fractures [39, 45–49], traumatic spine injuries [50–63], and spinal tuberculosis [64–68]. Other spinal conditions could be addressed in a similar manner. (See Online Supplement Tables 1, 2, and 3).

## Limitations

This paper is limited to spinal disorders defined in the scoping review; thus, not all spine disorders are included. Risk factors and associations do not imply causation. Diseases are multifactorial, and addressing any variable may not have a positive impact on a spinal disorder because the studies reviewed may not be applicable to the specific population. Caution is needed when making evidence-informed prevention recommendations for spinal disorders, as this is emerging literature. The scoping review that provided the data for this report included communities of all ranges of income

with a bias toward high-income countries. There are differences that should be considered when implementing our recommendations in low- and middle-income countries. First, access to health resources is often lower in low- and middle-income countries. Second, pain perception may be different among various cultures [69], potentially necessitating a different interpretation of prevention for painful conditions. Also, low- and middle-income countries often have a scarcity of registries, especially for spinal cord injuries, which may affect how important risk factors may be identified within these communities [51, 52]. While more research is needed in the prevention of spinal disorders, this review illustrates that spinal disorders are complex and usually multi-causal. Therefore, the multiple associated factors should be considered when investigating prevention in future studies. Multi-causation models may assist future epidemiological research efforts of spinal disorders when searching for solutions for improved public health [70–73].

## Conclusion

We identified 41 risk factors, 51 associations, and 39 comorbidities related to the 12 common spinal disorders. Biological, psychosocial, non-modifiable, and exposure variables existed in the risk factor and associations categories with interactions between these categories being mentioned frequently in the literature. Individual and community prevention strategies based upon risk, prognostic factors, and comorbidities for common spinal disorders can be included in the GSCI care pathway and model of care for the clinical environment and in the community. Prevention interventions should be selected based on the prevalence, local impact, and burden and with regard to local resource availability, community, and patient preferences. It is hoped that prevention interventions can be incorporated in more global regions, especially in underserved and low- and middle-income countries, to reduce spine care costs, morbidity, and mortality.

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## Compliance with ethical standards

**Conflict of interest** BNG receives speaker fees and travel reimbursement from NCMIC Speakers' Bureau; he is secretary of Brighthall Inc; the views in this article are those of the authors and not those of Stanford University, Stanford Health Care, or Qualcomm. CDJ is president of Brighthall Inc; she is an NCMIC Board of Director, however neither she nor NCMIC board make funding decisions for the NCMIC Foundation; the views in this article are those of the authors and not those of Stanford University, Stanford Health Care, or Qualcomm. SH

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## References

- Connelly LB, Woolf A, Brooks P (2006) Cost-effectiveness of interventions for musculoskeletal conditions. In: Jamison DT, Breman JG, Measham AR, Alleyne G, Claeson M, Evans DB et al (eds) *Disease control priorities in developing countries*, 2nd edn. World Bank, Washington, DC
- March L, Smith EU, Hoy DG, Cross MJ, Sanchez-Riera L, Blyth F et al (2014) Burden of disability due to musculoskeletal (MSK) disorders. *Best Pract Res Clin Rheumatol* 28(3):353–366
- Global Burden of Disease Study Collaborators (2015) Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 386(9995):743–800
- Hoy D, Geere JA, Davatchi F, Meggitt B, Barrero LH (2014) A time for action: opportunities for preventing the growing burden and disability from musculoskeletal conditions in low- and middle-income countries. *Best Pract Res Clin Rheumatol* 28(3):377–393
- Jackson T, Thomas S, Stabile V, Han X, Shotwell M, McQueen K (2015) Prevalence of chronic pain in low-income and middle-income countries: a systematic review and meta-analysis. *Lancet* 385(Suppl 2):S10
- Vancampfort D, Koyanagi A, Ward PB, Rosenbaum S, Schuch FB, Mugisha J et al (2017) Chronic physical conditions, multimorbidity and physical activity across 46 low- and middle-income countries. *Int J Behav Nutr Phys Act* 14(1):6
- Tsang A, Von Korff M, Lee S, Alonso J, Karam E, Angermeyer MC et al (2008) Common chronic pain conditions in developed and developing countries: gender and age differences and comorbidity with depression-anxiety disorders. *J Pain* 9(10):883–891
- Burns AS, O'Connell C (2012) The challenge of spinal cord injury care in the developing world. *J Spinal Cord Med* 35(1):3–8
- Chamberlain JD, Meier S, Mader L, von Groote PM, Brinkhof MW (2015) Mortality and longevity after a spinal cord injury: systematic review and meta-analysis. *Neuroepidemiology* 44(3):182–198
- Rasanathan K, Sivasankara Kurup A, Jaramillo E, Lonroth K (2011) The social determinants of health: key to global tuberculosis control. *Int J Tuberc Lung Dis* 15(Suppl 2):S30–S36
- Martin BI, Deyo RA, Mirza SK, Turner JA, Comstock BA, Hollingworth W et al (2008) Expenditures and health status among adults with back and neck problems. *JAMA* 299(6):656–664
- Stewart Williams J, Ng N, Peltzer K, Yawson A, Biritwum R, Maximova T et al (2015) Risk Factors and disability associated with low back pain in older adults in low- and middle-income countries. Results from the WHO study on global AGEing and adult health (SAGE). *PLoS ONE* 10(6):e0127880
- Louw QA, Morris LD, Grimmer-Somers K (2007) The prevalence of low back pain in Africa: a systematic review. *BMC Musculoskelet Disord* 8:105
- Rojas M, Gimeno D, Vargas-Prada S, Benavides FG (2015) Musculoskeletal pain in Central American workers: results of the first survey on working conditions and health in Central America. *Rev Panam Salud Publica* 38(2):120–128
- Spiegel DA, Gosselin RA, Coughlin RR, Joshipura M, Browner BD, Dormans JP (2008) The burden of musculoskeletal injury in low and middle-income countries: challenges and opportunities. *J Bone Joint Surg Am* 90(4):915–923
- Stewart Williams J, Kowal P, Hestekin H, O'Driscoll T, Peltzer K, Yawson A et al (2015) Prevalence, risk factors and disability associated with fall-related injury in older adults in low- and middle-income countries: results from the WHO Study on global AGEing and adult health (SAGE). *BMC Med* 13:147
- Wajed J, Ahmad Y, Durrington PN, Bruce IN (2004) Prevention of cardiovascular disease in systemic lupus erythematosus—proposed guidelines for risk factor management. *Rheumatology (Oxford)* 43(1):7–12
- Harari D, Hopper A, Dhese J, Babic-Illman G, Lockwood L, Martin F (2007) Proactive care of older people undergoing surgery ('POPS'): designing, embedding, evaluating and funding a comprehensive geriatric assessment service for older elective surgical patients. *Age Ageing* 36(2):190–196
- Haldeman S, Nordin M, Chou R, Côté P, Hurwitz EL, Johnson CD, Randhawa K et al (2018) The Global Spine Care Initiative: World Spine Care executive summary on reducing spine-related disability in low- and middle-income communities. *Eur Spine J*. <https://doi.org/10.1007/s00586-018-5722-x>
- Haldeman S, Johnson CD, Chou R, Nordin M, Côté P, Hurwitz EL et al (2018) The Global Spine Care Initiative: classification system for spine-related concerns. *Eur Spine J*. <https://doi.org/10.1007/s00586-018-5724-8>
- Haldeman S, Johnson CD, Chou R, Nordin M, Côté P, Hurwitz EL et al (2018) The Global Spine Care Initiative: care pathway for people with spine-related concerns. *Eur Spine J*. <https://doi.org/10.1007/s00586-018-5721-y>
- Johnson CD, Haldeman S, Chou R, Nordin M, Green BN, Côté P, Hurwitz EL et al (2018) The Global Spine Care Initiative: model of care and implementation. *Eur Spine J*. <https://doi.org/10.1007/s00586-018-5720-z>
- Johnson CD, Haldeman S, Nordin M, Chou R, Côté P, Hurwitz EL et al (2018) The Global Spine Care Initiative: methodology, contributors, and disclosures. *Eur Spine J*. <https://doi.org/10.1007/s00586-018-5723-9>
- Green BN, Johnson CD, Haldeman S, Griith E, Clay MB, Kane EJ et al (2018) A scoping review of biopsychosocial risk factors and co-morbidities for common spinal disorders. *PLOS ONE* 13(6):e0197987. <https://doi.org/10.1371/journal.pone.0197987>
- Tricco AC, Lillie E, Zarin W, O'Brien K, Colquhoun H, Kastner M et al (2016) A scoping review on the conduct and reporting of scoping reviews. *BMC Med Res Methodol* 16:15

26. International Association for the Study of Pain Taxonomy Working Group (2011) Classification of Chronic Pain. 2nd (revised) ed. International Association for the Study of Pain, Washington, DC. <http://www.iasp-pain.org/PublicationsNews/Content.aspx?ItemNumber=1673&navItemNumber=677>. Accessed 16 Oct 2016
27. Deyo RA, Weinstein JN (2001) Low back pain. *N Engl J Med* 344(5):363–370
28. Elfering A, Mannion AF (2008) Epidemiology and risk factors of spinal disorders. In: Boos N, Aebi M (eds) *Spinal disorders: fundamentals of diagnosis and treatment*. Springer, Berlin, pp 153–173
29. Haldeman S, Kopansky-Giles D, Hurwitz EL, Hoy D, Mark Erwin W, Dagenais S et al (2012) Advancements in the management of spine disorders. *Best Pract Res Clin Rheumatol* 26(2):263–280
30. Mathers C, Stevens G, Mascarenhas M (2009) *Global health risks: mortality and burden of disease attributable to selected major risks*. World Health Organization Press, Geneva
31. Friis RH, Sellers TA (2009) *Epidemiology for public health practice*, 4th edn. Jones and Bartlett Publishers, Sudbury, p 717
32. Rothstein WG (2003) *Public health and the risk factor: a history of an uneven medical revolution*. University of Rochester Press, Rochester, p 466
33. Valderas JM, Starfield B, Sibbald B, Salisbury C, Roland M (2009) Defining comorbidity: implications for understanding health and health services. *Ann Fam Med* 7(4):357–363
34. Starfield B, Hyde J, Gervas J, Heath I (2008) The concept of prevention: a good idea gone astray? *J Epidemiol Community Health* 62(7):580–583
35. Hill JC, Whitehurst DG, Lewis M, Bryan S, Dunn KM, Foster NE et al (2011) Comparison of stratified primary care management for low back pain with current best practice (STarT Back): a randomised controlled trial. *Lancet* 378(9802):1560–1571
36. Norris SL, Kansagara D, Bougatsos C, Fu R (2008) Force USPST. Screening adults for type 2 diabetes: a review of the evidence for the U.S. Preventive Services Task Force. *Ann Intern Med* 148(11):855–868
37. Vernon H (2008) The Neck Disability Index: state-of-the-art, 1991–2008. *J Manip Physiol Ther* 31(7):491–502
38. MacAvoy S, Skinner T, Hines M (1996) Fall risk assessment tool. *Appl Nurs Res* 9(4):213–218
39. Preventive US (2011) Services Task Force. Screening for osteoporosis: U.S. preventive services task force recommendation statement. *Ann Intern Med* 154(5):356–364
40. Harden CL, Meador KJ, Pennell PB, Hauser WA, Gronseth GS, French JA et al (2009) Management issues for women with epilepsy-Focus on pregnancy (an evidence-based review): II. Teratogenesis and perinatal outcomes: Report of the Quality Standards Subcommittee and Therapeutics and Technology Subcommittee of the American Academy of Neurology and the American Epilepsy Society. *Epilepsia* 50(5):1237–1246
41. World Health Organization (2006) *Guidelines for drinking-water quality*. World Health Organization, Geneva. [http://www.who.int/water\\_sanitation\\_health/dwq/gdwq0506.pdf](http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf). Accessed 2 Mar 2017
42. Scherer M, Hansen H, Gensichen J, Mergenthal K, Riedel-Heller S, Weyerer S et al (2016) Association between multimorbidity patterns and chronic pain in elderly primary care patients: a cross-sectional observational study. *BMC Fam Pract* 17:68
43. Jeremiah MP, Unwin BK, Greenawald MH, Casiano VE (2015) Diagnosis and management of osteoporosis. *Am Fam Phys* 92(4):261–268
44. McKenzie JF, Pinger RR, Kotecki KE (2008) Community organization/building and health promotion programming. In: McKenzie JF (ed) *An introduction to community health*. Jones and Bartlett Publishers, Sudbury, pp 120–144
45. Cosman F, de Beur SJ, LeBoff MS, Lewiecki EM, Tanner B, Randall S et al (2014) Clinician's guide to prevention and treatment of osteoporosis. *Osteoporos Int*. 25(10):2359–2381
46. Bolland MJ, Leung W, Tai V, Bastin S, Gamble GD, Grey A et al (2015) Calcium intake and risk of fracture: systematic review. *BMJ* 351:h4580
47. Reid IR, Bolland MJ, Grey A (2014) Effects of vitamin D supplements on bone mineral density: a systematic review and meta-analysis. *Lancet* 383(9912):146–155
48. Winzenberg TM, Shaw K, Fryer J, Jones G (2006) Calcium supplementation for improving bone mineral density in children. *Cochrane Database Syst Rev* 2:CD005119
49. Nguyen VH (2017) Community osteoporosis screening services for the prevention of osteoporotic fractures in population health: a literature review. *Int J Evid Based Healthc* 15(2):43–52
50. Dinh-Zarr TB, Sleet DA, Shults RA, Zaza S, Elder RW, Nichols JL et al (2001) Reviews of evidence regarding interventions to increase the use of safety belts. *Am J Prev Med* 21(4 Suppl):48–65
51. Lee BB, Cripps RA, Fitzharris M, Wing PC (2014) The global map for traumatic spinal cord injury epidemiology: update 2011, global incidence rate. *Spinal Cord* 52(2):110–116
52. Jazayeri SB, Beygi S, Shokraneh F, Hagen EM, Rahimi-Movaghar V (2015) Incidence of traumatic spinal cord injury worldwide: a systematic review. *Eur Spine J* 24(5):905–918
53. van den Berg ME, Castellote JM, de Pedro-Cuesta J, Mahillo-Fernandez I (2010) Survival after spinal cord injury: a systematic review. *J Neurotrauma* 27(8):1517–1528
54. Kraft R, Dorstyn D (2015) Psychosocial correlates of depression following spinal injury: a systematic review. *J Spinal Cord Med* 38(5):571–583
55. Craig A, Tran Y, Middleton J (2009) Psychological morbidity and spinal cord injury: a systematic review. *Spinal Cord* 47(2):108–114
56. Dijkers M, Bryce T, Zanca J (2009) Prevalence of chronic pain after traumatic spinal cord injury: a systematic review. *J Rehabil Res Dev* 46(1):13–29
57. Gilbert O, Croffoot JR, Taylor AJ, Nash M, Schomer K, Groah S (2014) Serum lipid concentrations among persons with spinal cord injury—a systematic review and meta-analysis of the literature. *Atherosclerosis* 232(2):305–312
58. Xing D, Wang J, Song D, Xu W, Chen Y, Yang Y et al (2013) Predictors for mortality in elderly patients with cervical spine injury: a systematic methodological review. *Spine (Phila Pa 1976)* 38(9):770–777
59. van Middendorp JJ, Albert TJ, Veth RP, Hosman AJ (2010) Methodological systematic review: mortality in elderly patients with cervical spine injury: a critical appraisal of the reporting of baseline characteristics, follow-up, cause of death, and analysis of risk factors. *Spine (Phila Pa 1976)* 35(10):1079–1087
60. World Health Organization (2007) *Preventing Injuries and violence: a guide for ministries of health*. World Health Organization, Geneva
61. World Health Organization (2013) *Global status report on road safety 2013*. World Health Organization, Geneva
62. Krug EG, Sminkey LA (2007) The role of the ministry of health in preventing injuries and violence. *Int J Inj Contr Saf Promot* 14(3):199–201
63. Cooper BS, Medley GF, Stone SP, Kibbler CC, Cookson BD, Roberts JA et al (2004) Methicillin-resistant *Staphylococcus aureus* in hospitals and the community: stealth dynamics and control catastrophes. *Proc Natl Acad Sci USA* 101(27):10223–10228
64. Lonnroth K, Castro KG, Chakaya JM, Chauhan LS, Floyd K, Glaziou P et al (2010) Tuberculosis control and elimination 2010–50: cure, care, and social development. *Lancet* 375(9728):1814–1829

65. Kamara E, Mehta S, Brust JC, Jain AK (2012) Effect of delayed diagnosis on severity of Pott's disease. *Int Orthop* 36(2):245–254
66. Rajasekaran S (2007) Buckling collapse of the spine in childhood spinal tuberculosis. *Clin Orthop Relat Res* 460:86–92
67. Rajasekaran S, Prasad Shetty A, Dheenadhayalan J, Shashidhar Reddy J, Naresh-Babu J, Kishen T (2006) Morphological changes during growth in healed childhood spinal tuberculosis: a 15-year prospective study of 61 children treated with ambulatory chemotherapy. *J Pediatr Orthop* 26(6):716–724
68. Lonnroth K, Migliori GB, Abubakar I, D'Ambrosio L, de Vries G, Diel R et al (2015) Towards tuberculosis elimination: an action framework for low-incidence countries. *Eur Respir J* 45(4):928–952
69. Rodrigues-De-Souza DP, Fernandez-De-Las-Penas C, Martin-Vallejo FJ, Blanco-Blanco JF, Moro-Gutierrez L, Alburquerque-Sendin F (2016) Differences in pain perception, health-related quality of life, disability, mood, and sleep between Brazilian and Spanish people with chronic non-specific low back pain. *Braz J Phys Ther* 20(5):412–421
70. Susser M, Susser E (1996) Choosing a future for epidemiology: I. Eras and paradigms. *Am J Public Health* 86(5):668–673
71. Krieger N, Zierler S (1996) What explains the public's health?—A call for epidemiologic theory. *Epidemiology* 7(1):107–109
72. Susser M, Susser E (1996) Choosing a future for epidemiology: II. From black box to Chinese boxes and eco-epidemiology. *Am J Public Health* 86(5):674–677
73. Broadbent A (2009) Causation and models of disease in epidemiology. *Stud Hist Philos Biol Biomed Sci* 40(4):302–311

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