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Association between Spinal Curvatures and Injury: A Nationwide Population-based Retrospective Cohort Study

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Abstract

Background and objective: Injury is an important issue in public health. Spinal curvatures are deformities characterized by abnormal curves of the spine. The prevalence of spinal curvature is not low, but its relationship with injury has not been studied. The aim of this study is to investigate whether spinal curvature increases the risk of injury.

Methods: This retrospective cohort study uses data from the Taiwan National Health Insurance Research Database (NHIRD) from 2000 to 2010. Patients with spinal curvatures were selected using codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). A cohort without spinal curvature was randomly frequency-matched to the spinal curvature cohort at a ratio of 2:1 according to age, sex, and index year. The risk of injury was analyzed using Cox's proportional hazards regression models adjusting for age, sex, comorbidities, urbanization level, and socioeconomic status.

Results: A total of 20,566 patients with spinal curvatures and 41,132 controls were enrolled in this study. The risk of injury was 2.209 times higher (95% CI 2.118 to 2.303) in patients with spinal curvature than in the control group. The spinal curvature cohort exhibited higher risk of developing injury compared to the control group, regardless of age, sex, comorbidities, urbanization level, and subgroup of spinal curvatures. Based on the subgroup analysis, the spinal curvature cohort had higher risks of unintentional injury and injury diagnoses such as fracture, dislocation, open wound, superficial injury/contusion, crushing, and injury to nerves and spinal cord compared to the control cohort.

Conclusions: Patients with spinal curvatures have a significantly higher risk of developing injury than patients without spinal curvatures. Aggressive detection and management of spinal curvatures may be beneficial for injury prevention.

Short title: Relationship between spinal curvatures and injury

Keywords: injury, spinal curvature, kyphosis, lordosis, scoliosis, risk factor

Conflicts of interest

The authors declare that they have no conflict of interest.

Author Contributions:

Yen-Liang Kuo, Chih-Hao Shen and Wu-Chien Chien led the project and interpreted the data. Chi-Hsiang Chung, Tsai-Wang Huang and Chang-Huei Tsao conducted this study and analyzed the data. Shan-Yueh Chang, Chung-Kan Peng and Wei-Erh Cheng interpreted the data. Yen-Liang Kuo, Chih-Hao Shen and Wu-Chien Chien wrote the paper. All authors approved the final version of manuscript.

Strengths and limitations of this study:

- This is the first nationwide population-based cohort study assessing the associations between spinal curvature and injury.
- Patients with spinal curvature have 2.209-fold higher risk of developing injury compared to those without spinal curvature.
- Based on the subgroup analysis, the spinal curvature cohort has higher risks of unintentional injury compared to the control cohort.
- The main strengths of this study are the large population-based dataset and the retrospective cohort design which minimize the selection bias and describe the sequential association between spinal curvature and injury.
- The main limitation of this study is the characteristic of the database. Detailed information such as severity of spinal curvature, lifestyle, behavior patterns, obesity and bone mineral density are not available for further analysis.

Ethics

Because data were collected from the Taiwan National Health Insurance Research Database and 1,000,000 people were randomly selected from the entire population, personal medical information about an identifiable person is not contained in this database and Ethics Committee/Institutional Review Board approval or patient consent was not necessary.

Funding

There is no funding for this submission.

Data sharing statement

No additional data available.

Introduction

Spinal curvatures are deformities characterized by abnormal curves of the spine and can be divided into lordosis, kyphosis, and scoliosis. Lordosis refers to anteroposterior angulation and inward curving of the lumbar spine. Kyphosis and scoliosis and can be graded in severity by the Cobb angle (1). Kyphosis is the anteroposterior angulation and outward curve of the thoracic spine. Generally, Cobb angle of normal thoracic spine ranges between 20 and 50 degrees in young people (2, 3). Scoliosis indicates lateral displacement or curvature of the spine. In adult, a curve in spine of 10 degrees or greater of Cobb angle is defined as scoliosis (4). Among community-dwelling individuals ≥ 60 years old, the current incidence of spinal curvatures is between 20 and 40 percent (5-7). There are multiple contributing factors to spinal curvature, such as vertebral fractures with low bone density (8-10), short vertebral height as in Scheuermann disease (11), degenerative disc disease (12), postural changes, muscle weakness, and intervertebral ligament degeneration.

Injury is an important issue in public health (13), especially among the elderly (14). Injuries can be divided into several types according to various factors, such as injury diagnosis, cause of injury, or intentionality of injury according to the National Health Insurance Research Database (NHIRD) of Taiwan (15). The occurrence of injury influences the capacity for activity and can cause complications, economic burden, and even mortality (16-19). Thus, determining the modifiable risks and strategies for the prevention or management of injury deserves more clinical attention.

The potential relationship between spinal curvature and injury is not precisely known. Sinaki et al. demonstrated that thoracic hyperkyphosis in the context of reduced muscle strength plays an important role in increasing body sway, gait unsteadiness, and risk of falls in osteoporosis (20). De Groot et al. suggest that patients with flexed posture (characterized by protrusion of the head and increased thoracic kyphosis) have impaired postural control during walking and may therefore have higher risk of falling (21). However, no study has described the sequential association between curvature of the spine and injury. We conducted a nationwide population-based cohort study to investigate whether spinal curvature increases the risk of injury.

Materials and Methods

Data sources

Taiwan's NHIRD has been built since Taiwan established a universal health care system in 1995. This database includes the medical records of the Taiwanese population of around 23.81 million, and the coverage reached 99.6% in 2016. In this study, data were collected from the NHIRD, and 1,000,000 people were randomly selected from the entire population. The disease diagnosis codes in the NHIRD dossier are based on the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

Study design and sampled participants

This study was a retrospective cohort design. Patients were selected if they were diagnosed with spinal curvature with ≥ 3 outpatient visits and spinal-curvature inpatients from January 2, 2000, to December 31, 2010, according to the following ICD-9 codes: kyphosis (ICD-9-CM 737.0, 737.1, 737.41), lordosis (ICD-9-CM 737.2, 737.42), kyphoscoliosis and scoliosis (ICD-9-CM 737.3, 737.43), and unspecified (ICD-9-CM 737.40, 737.8, 737.9) from the Longitudinal Health Insurance Database (LHID). Patients were excluded for the following reasons: 1) spinal curvature diagnosed before 2000, 2) injury before tracing, 3) age < 20 years, and 4) unknown gender. The patients were divided into four groups based on the ICD codes.

For the control cohort, we randomly selected patients without spinal curvature in this period from among insured individuals. We excluded control subjects according to the same criteria. The spinal curvature cohort and control cohort were frequency matched by gender, age, and index rate (Figure 1).

Outcome measures

All study participants were followed from the index date until the first diagnosis of injury (ICD-9-CM 800–999), withdrawal from the National Health Insurance (NHI) program, or the end of 2010. Based on the definition of injury categories from prior studies (15, 22), the causes of injury were classified as traffic injuries (ICD-9-CM E800-E849), poisoning (ICD-9-CM E850-E869), falls (ICD-9-CM E880-E888), burns and fires (ICD-9-CM E890-E899), drowning (ICD-9-CM E910), suffocation (ICD-9-CM E911-E915), crushing/cutting/piercing (ICD-9-CM E916-E920), other unintentional injuries (ICD-9-CM E870-E879, E900-E909, E951-E949). The intentionality categories of injuries include unintentional (ICD-8-CM E800-R949), intentional (ICD-9-CM E950-E979, E990-E999), and unknown.

Comorbidities

Baseline comorbidities include diabetes (ICD-9-CM 250), hypertension (ICD-9-CM 401 – 405), ischemic heart disease (ICD-9-CM codes 410–414), stroke (ICD-9-CM 430-438), chronic kidney disease (ICD-9-CM 585), liver cirrhosis (ICD-9-CM 570, 571, 572.1, 572.4, 573.1–573.3), chronic obstructive lung disease (ICD-9-CM codes 490, 491, 495, and 496), and cancer (ICD-9-CM 140-208). The population was also stratified according to the number of comorbidities (0, 1, and ≥ 2).

Statistical analysis

All analyses were performed using the Statistical Package for the Social Sciences

(SPSS) (V.21; SPSS Inc., Chicago, Illinois, USA). Chi squared and t tests were used to evaluate the distributions of categorical and continuous variables between patients with spinal curvature and the control group. The incidence rates of injury were calculated according to gender, age, number of comorbidities, urbanization level, and insurance premium. Multivariable Cox proportional hazards regression models were used to determine the risk of injury, which is presented as a hazard ratio (HR) with a 95% confidence interval (CI). The difference in injury risk between the two groups was estimated using the Kaplan-Meier method with the log-rank test. A two-tailed p value < 0.05 was considered significant.

Results

We enrolled 20,566 patients who had spinal curvature and 41,132 subjects without spinal curvature in the control group. The majority of patients were ≥ 65 years old (52.82% and 51.58% for spinal curvature and control group, respectively). Females accounted for more than half of the subjects (64.61%) in each cohort. There is a significant difference in the number of comorbidities, urbanization level, and insurance premium between the spinal curvature group and control group (Table 1). The average period of follow-up was 5.48 years for the spinal curvature cohort and 6.24 years for the control group.

Table 2 shows that the incidence of injury was higher in the spinal curvature cohort than that in the control cohort (10905.25 and 9059.47 incidences per 100,000 person-years, respectively). Compared to the control group, spinal curvature patients were associated with a significantly higher risk of injury (adjusted HR 2.209 (95% CI 2.118 to 2.303)). The spinal curvature cohort exhibited a higher risk of injury compared to the control group, regardless of age, sex, comorbidities, and urbanization level. The risk of injury was also significantly higher in the spinal curvature cohort than in the control cohort among patients with insurance premiums < 18,000 New Taiwan dollars (NTD) and 18,000-34,999 NTD. Table 3 shows the risks of injury stratified by subgroup of spinal curvature (kyphosis, lordosis, kyphoscoliosis and scoliosis, and unspecified type). All subgroups of spinal curvature had a significantly higher risk of injury compared to the control cohort (adjusted HR 2.777 (95% CI 2.553 to 3.021), 2.087 (95% CI 1.235 to 3.527), 2.113 (95% CI 2.021 to 2.210), 2.727 (95% CI 2.119 to 3.509), respectively).

Table 4 shows the incidence and adjusted HR of injury according to the injury diagnosis, cause of injury, and intentionality of injury at the end of the follow-up period. The spinal curvature cohort had a significantly higher risk of unintentionality of injury compared to the control cohort (adjusted HR 1.537 (95% CI 1.200 to 2.605)). The spinal curvature cohort had significantly higher risk in injury diagnoses of fracture, dislocation, open wound, superficial injury/contusion, crushing, injury to nerve and spinal cord, and other injury compared to the control cohort (adjusted HR 1.502 (95% CI 1.398 to 1.614), 1.732 (95% CI 1.172 to 2.558), 1.597 (95% CI 1.310 to 1.939), 1.414 (95% CI 1.131 to 1.761), 4.949 (95% CI 1.093 to 30.895), 2.428 (95% CI 1.310 to 4.500), and 1.387 (95% CI 1.284 to 1.499), respectively). They also had significantly higher risk of traffic injuries, falls, suffocation, crushing/cutting/piercing, and other injuries compared to the control cohort (adjusted HR 1.379 (95% CI 1.191 to 1.597), 1.552 (95% CI 1.429 to 1.686), 6.442 (95% CI 2.335 to 17.776), 2.595 (95% CI 1.056 to 3.409), and 1.612 (95% CI 1.443 to 1.800), respectively). Significantly higher risk of unitentional injury was also observed in the spinal curvature cohort (1.537 (95% CI 1.200 to 2.605)).

We used Kaplan-Meier survival analysis to assess the cumulative incidence. There were significant differences in the cumulative incidence of injury among the patients with and without spinal curvature from the 1st to the 11th follow-up year (log-rank test; p<0.001) (Figure 2).

Discussion

This is the first nationwide population-based cohort study to investigate the associations between spinal curvature and injury. We found that patients with spinal curvature had 2.209-fold higher risk of developing injury compared to those without spinal curvature. Although the spinal curvature and non- spinal curvature cohorts had different prevalence of comorbidities, urbanization level, and insurance premium on the index day, spinal curvature remained an independent risk factor for injury in the adjusted Cox regression analysis. As shown in Table 2, patients in the spinal curvature cohort had a higher incidence of injury than patients in the control cohort in most of the subgroup analyses of sex, age, comorbidity, urbanization level and socioeconomic status. This observation strengthens the finding that spinal curvature independently increases the risk of injury.

For subgroup analysis of injury events, we found that patients with spinal curvature had higher risk of unintentional injury and injury diagnoses such as fracture, dislocation, open wound, superficial injury/contusion, crushing, and injury to nerves and spinal cord. The severity of spinal curvature is defined by the measurement of the Cobb angle of curvature (1). Chest wall compliance decreases in severe cases, which leads to difficulty in breathing, increased risk of respiratory muscle fatigue (23, 24), increased dead space fraction, alveolar hypoventilation with hypercapnia (25), hypoxemia (26), ventilation-perfusion mismatch, apneic events with nocturnal hypoventilation and arterial oxygen desaturation (23, 27), and exercise limitations (28, 29). Previous studies also suggest that spinal curvature is associated with reduced muscle strength, increased body sway, and gait unsteadiness (20, 30-32). The increased risk of unintentional injury in our study may be explained by these systemic manifestations of spinal curvature.

We found that patients with spinal curvature had higher risks of various injury causes, such as traffic injuries, falls, suffocation, crushing/cutting/piercing, and other unintentional injuries. Among these causes, risk of suffocation (adjusted HR 6.442) was much higher than that of other injuries. Although respiratory muscle fatigue (15, 16) and lung function impairment were found in patients with spinal curvature (17), there are insufficient studies explaining the mechanism between spinal curvature and suffocation. Further studies for analyzing this correlation are warranted.

After stratifying patients with injury by age, we found that the adjusted HR of subjects aged 20 to 40 years and 41 to 64 years were much higher than in those aged 65 years and above (adjusted HR, 6.665, 6.154, and 1.666, respectively). This contrasts with the concept that injury risk is higher among the elderly, especially for fracture due to car crashes (33). It is possible that daily activity among the younger population with spinal curvature is not limited, and the risk of injury is increased due to balance disorder and impaired postural control (34).

The treatment of spinal curvature includes supportive care, bracing, pulmonary rehabilitation, noninvasive ventilation, and surgery (35-39). Treatment may also improve pulmonary function, exercise capacity, and arterial blood gas, as well as eliminate obstructive apnea (40). Since spinal curvature was associated with higher risk of injury, providing assistive devices or protective gear to patients with spinal curvature may decrease the incidence of injury and may be practical for public health. Future studies focusing on the association between early detection, adequate treatment of spinal curvature, and the prevention of injury are warranted.

This study has some limitations. Firstly, the severity of spinal curvatures, the subjective symptoms and physical examinations were not recorded, which might confound the incidence rate of spinal curvatures. Secondly, there is no information on patient characteristics from the NHIRD. The data lacked information about smoking, dietary habits, alcoholism, substance use, obesity and bone mineral density, which might influence the time and incidence rate of injury occurrence. Thirdly, the severity of injuries that would impact the patient's daily life was not evaluated. Fourthly, other bias might remain in this retrospective cohort study, despite the meticulous adjustment of the model for potential confounders.

In conclusion, our study suggests that patient with spinal curvature exhibit higher risk of developing injury than patients without spinal curvature, especially the risks of unintentional injury and injury diagnoses such as fracture, dislocation, open wound, superficial injury/contusion, crushing, and injury to nerves and spinal cord.

Aggressive detection and management of patients with spinal curvature may be beneficial for injury prevention from a public health perspective.

Reference

1. JR C. Outline for the study of scoliosis. . American Academy of Orthopaedic Surgeons Instr Course Lect. 1948;5:15.
2. Fon GT, Pitt MJ, Thies AC, Jr. Thoracic kyphosis: range in normal subjects. AJR Am J Roentgenol. 1980;134(5):979-83.
3. Boseker EH, Moe JH, Winter RB, Koop SE. Determination of "normal" thoracic kyphosis: a roentgenographic study of 121 "normal" children. J Pediatr Orthop. 2000;20(6):796-8.
4. Kane WJ. Scoliosis prevalence: a call for a statement of terms. Clin Orthop Relat Res. 1977(126):43-6.
5. Kado DM, Huang MH, Karlamangla AS, Barrett-Connor E, Greendale GA. Hyperkyphotic posture predicts mortality in older community-dwelling men and women: a prospective study. J Am Geriatr Soc. 2004;52(10):1662-7.
6. Ryan SD, Fried LP. The impact of kyphosis on daily functioning. J Am Geriatr Soc. 1997;45(12):1479-86.
7. Takahashi T, Ishida K, Hirose D, Nagano Y, Okumiya K, Nishinaga M, et al. Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. Osteoporos Int. 2005;16(3):273-9.
8. Ensrud KE, Black DM, Harris F, Ettinger B, Cummings SR. Correlates of kyphosis in older women. The Fracture Intervention Trial Research Group. J Am Geriatr Soc. 1997;45(6):682-7.
9. Kado DM, Huang MH, Karlamangla AS, Cawthon P, Katzman W, Hillier TA, et al. Factors associated with kyphosis progression in older women: 15 years' experience in the study of osteoporotic fractures. J Bone Miner Res. 2013;28(1):179-87.
10. Pavlovic A, Nichols DL, Sanborn CF, Dimarco NM. Relationship of thoracic kyphosis and lumbar lordosis to bone mineral density in women. Osteoporos Int. 2013;24(8):2269-73.
11. Axenovich TI, Zaidman AM, Zorkoltseva IV, Kalashnikova EV, Borodin PM. Segregation analysis of Scheuermann disease in ninety families from Siberia. Am J Med Genet. 2001;100(4):275-9.

12. Schneider DL, von Muhlen D, Barrett-Connor E, Sartoris DJ. Kyphosis does not equal vertebral fractures: the Rancho Bernardo study. J Rheumatol. 2004;31(4):747-52.

13. Haagsma JA, Graetz N, Bolliger I, Naghavi M, Higashi H, Mullany EC, et al. The global burden of injury: incidence, mortality, disability-adjusted life years and time trends from the Global Burden of Disease study 2013. Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention. 2016;22(1):3-18.

14. Yeo YY, Lee SK, Lim CY, Quek LS, Ooi SB. A review of elderly injuries seen in a Singapore emergency department. Singapore Med J. 2009;50(3):278-83.

15. Chien WC, Chung CH, Lai CH, Chou CH. A retrospective population-based study of injury types among elderly in Taiwan. International journal of injury control and safety promotion. 2014;21(1):3-8.

16. National estimates of the ten leading causes of nonfatal injuries, Centers for Disease Control and Prevention. CDC. 2004;www.cdc.gov/injury/wisqars.html (Accessed on May 24, 2010).

17. Mackenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, et al. The National Study on Costs and Outcomes of Trauma. J Trauma. 2007;63(6 Suppl):S54-67; discussion S81-6.

18. Global burden of disease. World Health Organization. 2010; www.who.int/healthinfo/global_burden_disease/en/ (Accessed on May 01, 2010).

19. Global Status on Road Safety. World Health Organization. 2015;http://www.who.int/violence_injury_prevention/road_safety_status/2015/ (Accessed on April 04, 2016).

20. Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. Osteoporos Int. 2005;16(8):1004-10.

21. de Groot MH, van der Jagt-Willems HC, van Campen JP, Lems WF, Beijnen JH, Lamoth CJ. A flexed posture in elderly patients is associated with impairments in postural control during walking. Gait Posture. 2014;39(2):767-72.

22. Lin CL, Chung CH, Tsai YH, Chien WC. Association between sleep disorders and injury: a nationwide population-based retrospective cohort study. Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention. 2016;22(5):342-6.

23. Jones RS, Kennedy JD, Hasham F, Owen R, Taylor JF. Mechanical inefficiency of the thoracic cage in scoliosis. Thorax. 1981;36(6):456-61.

24. Di Bari M, Chiarlone M, Matteuzzi D, Zacchei S, Pozzi C, Bellia V, et al. Thoracic kyphosis and ventilatory dysfunction in unselected older persons: an

epidemiological study in Dicomano, Italy. J Am Geriatr Soc. 2004;52(6):909-15.

25. Bergofsky EH, Turino GM, Fishman AP. Cardiorespiratory failure in kyphoscoliosis. Medicine (Baltimore). 1959;38:263-317.

26. Naeye RL. Kyphoscoliosis and cor pulmonale; a study of the pulmonary vascular bed. Am J Pathol. 1961;38:561-73.

27. Shannon DC, Riseborough EJ, Kazemi H. Ventilation perfusion relationships following correction of kyphoscoliosis. JAMA. 1971;217(5):579-84.

28. Shneerson JM. The cardiorespiratory response to exercise in thoracic scoliosis. Thorax. 1978;33(4):457-63.

29. Kesten S, Garfinkel SK, Wright T, Rebuck AS. Impaired exercise capacity in adults with moderate scoliosis. Chest. 1991;99(3):663-6.

30. Lynn SG, Sinaki M, Westerlind KC. Balance characteristics of persons with osteoporosis. Arch Phys Med Rehabil. 1997;78(3):273-7.

31. de Groot MH, van der Jagt-Willems HC, van Campen JP, Lems WF, Lamoth CJ. Testing postural control among various osteoporotic patient groups: a literature review. Geriatr Gerontol Int. 2012;12(4):573-85.

32. Katzman WB, Vittinghoff E, Kado DM, Lane NE, Ensrud KE, Shipp K. Thoracic kyphosis and rate of incident vertebral fractures: the Fracture Intervention Trial. Osteoporos Int. 2016;27(3):899-903.

33. Brorsson B. Age and injury severity. Scand J Soc Med. 1989;17(4):287-90.

34. Gauchard GC, Lascombes P, Kuhnast M, Perrin PP. Influence of different types of progressive idiopathic scoliosis on static and dynamic postural control. Spine (Phila Pa 1976). 2001;26(9):1052-8.

35. Skaggs DL, Bassett GS. Adolescent idiopathic scoliosis: an update. Am Fam Physician. 1996;53(7):2327-35.

36. Weinstein SL, Dolan LA, Wright JG, Dobbs MB. Effects of bracing in adolescents with idiopathic scoliosis. N Engl J Med. 2013;369(16):1512-21.

37. Negrini S, Minozzi S, Bettany-Saltikov J, Chockalingam N, Grivas TB, Kotwicki T, et al. Braces for idiopathic scoliosis in adolescents. Cochrane Database Syst Rev. 2015(6):CD006850.

38. Fuschillo S, De Felice A, Martucci M, Gaudiosi C, Pisano V, Vitale D, et al. Pulmonary rehabilitation improves exercise capacity in subjects with kyphoscoliosis and severe respiratory impairment. Respir Care. 2015;60(1):96-101.

39. Obayashi H, Urabe Y, Yamanaka Y, Okuma R. Effects of respiratory-muscle exercise on spinal curvature. J Sport Rehabil. 2012;21(1):63-8.

40. Menon B, Aggarwal B. Influence of spinal deformity on pulmonary function, arterial blood gas values, and exercise capacity in thoracic kyphoscoliosis. Neurosciences (Riyadh). 2007;12(4):293-8.

Figure Legends

Figure 1. Flowchart of the study

Figure 2. Kaplan-Meier curve for cumulative risk of injury

Table 1. Demographic data for patients with and without spinal curvature

	Curvature of the spine				*p value*
	with		without		
Variables	n	%	n	%	
Total	20,566	33.33	41,132	66.67	
Gender					0.999
Male	7,279	35.39	14,558	35.39	
Female	13,287	64.61	26,574	64.61	
Age group (years)					0.999
20-40	3,107	15.11	6,529	15.87	
41-64	6,597	32.08	13,386	32.54	
≧65	10,862	52.82	21,217	51.58	
Number of comorbidities					<0.001
0	12,469	60.63	19,513	47.44	
1	6,074	29.53	12,021	29.23	

≧2	2,023	9.84	9,598	23.33	
Urbanization level					<0.001
1 (The highest)	8,147	39.61	14,344	34.87	
2	7,807	37.96	17,780	43.23	
3	2,021	9.83	2,946	7.16	
4 (The lowest)	2,591	12.60	6,062	14.74	
Insurance premium (NT$)					<0.001
<18,000	20,193	98.19	40,541	98.56	
18,000-34,999	324	1.58	482	1.17	
≧35,000	49	0.24	109	0.27	

Table 2. Risk of injury stratified by variables

Variables	With curvature of the spine			Without curvature of the spine			Ratio	Adjusted HR†(95%CI)
	Event	PYs	IR‡ (per 10^5 PYs)	Event	PYs	IR‡ (per 10^5 PYs)		
Total	3,617	33,167.52	10,905.25	6,254	69,032.77	9,059.47	1.204	2.209 (2.118-2.303) *
Gender								
Male	1,308	12,003.99	10,896.38	2,288	24,100.91	9,493.42	1.148	2.098 (1.958-2.249) *
Female	2,309	21,163.52	10,910.28	3,966	44,931.86	8,826.70	1.236	2.279 (2.162-2.402) *
Age group (years)								
20-40	289	2,945.11	9,812.88	177	6,082.11	2,910.17	3.372	6.665 (5.512-8.060) *
41-64	885	7,561.59	11,703.89	603	8,360.88	7,212.16	1.623	6.154 (5.527-6.852) *
≧65	2,443	22,660.82	10,780.72	5,474	54,589.78	10,027.52	1.075	1.666 (1.587-1.749) *
Number of comorbidities								
0	2,008	14,400.78	13,943.69	2,653	22,738.69	11,667.34	1.195	2.424 (2.284-2.572) *
1	1,142	11,337.55	10,072.72	2,077	21,977.53	9,450.56	1.066	2.203 (2.047-2.371) *
≧2	467	7,429.19	6,286.02	1,524	24,316.54	6,267.34	1.003	1.674 (1.507-1.860) *
Urbanization level								
1 (The highest)	1,012	9,790.98	10,336.04	1,759	20,803.62	8,455.26	1.222	2.225 (2.056-2.409) *

2	1,522	14,516.01	10,484.97	2,813	31,263.20	8,997.80	1.165	2.145 (2.012-2.285) *
3	325	2,422.89	13,413.73	463	4,925.73	9,399.62	1.427	2.766 (2.390-3.202) *
4 (The lowest)	758	6,437.64	11,774.50	1,219	12,040.22	10,124.40	1.163	2.131 (1.942-2.339) *
Insurance premium (NT$)								
<18,000	3,545	32,458.79	10,921.54	6,161	67,962.43	9,065.30	1.205	2.210 (2.118-2.305) *
18,000-34,999	68	643.84	10,561.63	88	965.58	9,113.69	1.159	2.297 (1.651-3.194) *
≧35,000	4	64.89	6,164.28	5	104.76	4,772.81	1.292	1.868 (0.430-8.119) **

*p<0.001; **p=0.405

†Adjusted HR: multivariable analysis including gender, age, number of comorbidities, urbanization level, and insurance premium.

‡Indicates incidence rate per 100,000 person-years.

IR, incidence rate; PYs = Person-years; Adjusted HR = Adjusted Hazard ratio; CI = confidence interval

Table 3. Risk of injury stratified by subgroup of spinal curvature

Curvature of the spine	Crude HR (95% CI)	Adjusted HR † (95%CI)
Kyphosis		
With	1.579	2.777 (2.553 - 3.021) *
Without	1 (Reference)	1 (Reference)
Lordosis		
With	1.033	2.087 (1.235 - 3.527) **
Without	1 (Reference)	1 (Reference)
Kyphoscoliosis and scoliosis		
With	1.146	2.113(2.201 - 2.210) *
Without	1 (Reference)	1 (Reference)
Unspecified		
With	1.388	2.727(2.119 - 3.509) *
Without	1 (Reference)	1 (Reference)

ICD-9-CM code: kyphosis (ICD-9-CM 737.0, 737.1, 737.41), lordosis (ICD-9-CM 737.2, 737.42), kyphoscoliosis and scoliosis (ICD-9-CM 737.3, 737.43), and unspecified (ICD-9-CM 737.40, 737.8, 737.9)

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical

Modification

*p< 0.001

**p=0.006

†Adjusted HR: multivariable analysis including gender, age, comorbidities, urbanization level, and insurance premium.

Adjusted HR = Adjusted Hazard ratio; CI = confidence interval

Table 4. Risk of injury stratified by injury diagnosis, cause of injury, and intentionality of injury in the end of follow-up

	Crude HR (95%CI)	Adjusted HR † (95%CI)
Injury diagnosis		
Fracture	1.193	1.502 (1.398-1.614) *
Dislocation	1.859	1.732 (1.172-2.558) *
Sprains and strains	1.510	1.341 (0.927-1.942)
Intracranial/internal injury	0.835	0.996 (0.808-1.501)
Open wound	1.244	1.597 (1.310-1.939) *
Injury to blood vessels	0.297	0.287 (0.007-11.122)
Superficial injury/contusion	1.321	1.414 (1.131-1.761) *
Crushing	4.460	4.949 (1.093-30.895) *
Foreign body entering through orifice	1.469	1.921 (0.970-3.803)
Burn	2.018	1.453 (0.968-2.180)
Injury to nerves and spinal cord	2.379	2.428 (1.310-4.500) *
Poisoning	0.999	0.983 (0.809-1.602)
Others injury	1.270	1.387 (1.284-1.499) *

Cause of injury		
Traffic injuries	1.370	1.379 (1.191-1.597) *
Poisoning	1.150	1.423 (0.906-2.234)
Falls	1.258	1.552 (1.429-1.686) *
Burns and fires	2.498	1.567 (0.977-2.567)
Drowning	N/A	N/A
Suffocation	1.972	6.442 (2.335-17.776) *
Crushing/cutting/piercing	1.788	2.595 (1.056-3.409) *
Other injuries	1.401	1.612 (1.443-1.800) *
Intentionality of injury		
Unitentional	1.335	1.537 (1.200-2.605) *
Intentional	2.330	2.218 (0.994-3.424)
Unknown	1.095	1.076 (0.419-1.830)

*p<0.05

Some patients did not provide information about cause and intentionality of injury

†Adjusted HR: multivariable analysis including gender, age, comorbidities, urbanization level, and insurance premium.

Adjusted HR = Adjusted Hazard ratio; CI = confidence interval

N/A: non-applicable due to only one drowning event in spine curvature patients and no drowning event in the control group.

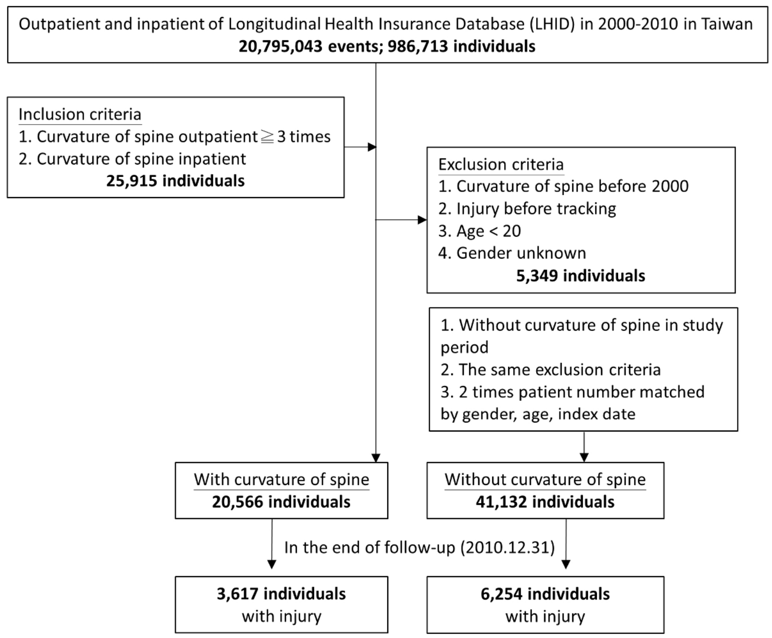

Figure 1. The flowchart of study sample selection from National Health Insurance Research Database in Taiwan

190x274mm (284 x 284 DPI)

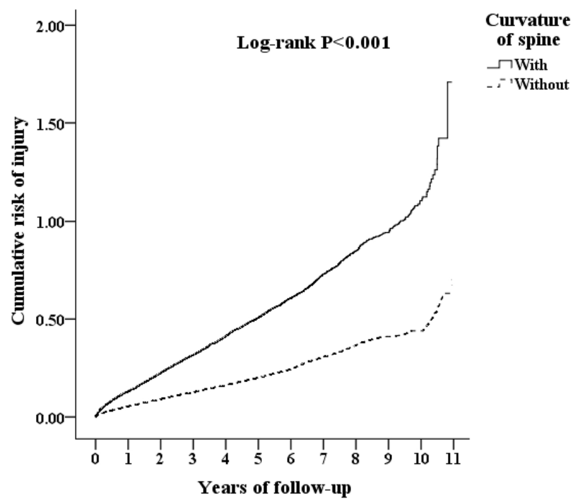

Figure 2. Kaplan-Meier for cumulative risk of injury among aged 20 over stratified by curvature of spine with log-rank test

190x274mm (284 x 284 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Summarise follow-up time (eg, average and total amount)
Outcome data	15*	Report numbers of outcome events or summary measures over time
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

Association between Spinal Curvature Disorders and Injury: A Nationwide Population-based Retrospective Cohort Study

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Association between Spinal Curvature Disorders and Injury: A Nationwide Population-based Retrospective Cohort Study

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Abstract

Objectives: Injury is an important issue in public health. Spinal curvature disorders are deformities characterized by excessive curves of the spine. The prevalence of spinal curvature disorders is not low, but its relationship with injury has not been studied. The aim of this study is to investigate whether spinal curvature disorders increases the risk of injury.

Design: Population-based retrospective cohort study.

Setting: Using data from the Taiwan National Health Insurance Research Database (NHIRD) from 2000 to 2010.

Participants and exposure: Patients with spinal curvature disorders were selected using codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). A cohort without spinal curvature was randomly frequency-matched to the spinal curvature disorders cohort at a ratio of 2:1 according to age, sex, and index year.

Primary outcome measures: The risk of injury was analyzed using Cox's proportional hazards regression models adjusting for age, sex, comorbidities, urbanization level, and socioeconomic status.

Results: A total of 20,566 patients with spinal curvature disorders and 41,132 controls were enrolled in this study. The risk of injury was 2.209 times higher (95%

CI 2.118 to 2.303) in patients with spinal curvature disorders than in the control group. The spinal curvature disorders cohort exhibited higher risk of developing injury compared to the control group, regardless of age, sex, comorbidities, urbanization level, and subgroup of spinal curvature disorders. Based on the subgroup analysis, the spinal curvature disorders cohort had higher risks of unintentional injury and injury diagnoses such as fracture, dislocation, open wound, superficial injury/contusion, crushing, and injury to nerves and spinal cord compared to the control cohort.

Conclusions: Patients with spinal curvature disorders have a significantly higher risk of developing injury than patients without spinal curvature disorders. Aggressive detection and management of spinal curvature disorders may be beneficial for injury prevention.

Short title: Relationship between spinal curvature disorders and injury

Keywords: injury, spinal curvature disorders, spinal curvature, kyphosis, lordosis, scoliosis, risk factor

Conflicts of interest

The authors declare that they have no conflict of interest.

Author Contributions:

Yen-Liang Kuo, Chih-Hao Shen and Wu-Chien Chien led the project and interpreted the data. Chi-Hsiang Chung, Tsai-Wang Huang and Chang-Huei Tsao conducted this study and analyzed the data. Shan-Yueh Chang, Chung-Kan Peng and Wei-Erh Cheng interpreted the data. Yen-Liang Kuo, Chih-Hao Shen and Wu-Chien Chien wrote the paper. All authors approved the final version of manuscript.

Strengths and limitations of this study:

- This is the first nationwide population-based cohort study to assess the associations between spinal curvature and injury.
- The main strengths of this study are the large population-based dataset and the retrospective cohort design, which minimize selection bias.
- This study cohort is large enough to examine each risks of injury among subgroups.
- The limitation of this study is the lack of information on the severity of spinal curvature disorders, detailed patient characteristics, and injury severity.

Ethics

Because data were collected from the Taiwan National Health Insurance Research Database and 1,000,000 people were randomly selected from the entire population, personal medical information about an identifiable person is not contained in this database and patient consent was not necessary. This study was approved after a complete ethical review by the Institutional Review Board (IRB) of National Defense Medical Center Tri-Service General Hospital (approval number: TSGHIRB No. 1-105-05-142).

Funding statement

There is no funding for this submission.

Data sharing statement

No additional data available.

Introduction

The spine has a gentle curve when viewed from the side and a straight appearance when viewed from the back. This structure absorbs the stress from body movement and gravity. Kyphosis is a convex curvature of the spine that creates a hunchback appearance. Lordosis refers to the inward concave curving of the cervical and lumbar regions of the spine[1 2]. When disorders of the spine occur, the natural curvatures of the spine are misaligned or exaggerated in certain areas.

Possible spinal curvature disorders include scoliosis, hyperkyphosis, and hyperlordosis, which can be graded in severity by the Cobb angle [3]. Scoliosis indicates a lateral displacement or curvature of the spine [4], which is defined by a curve in the spine with a Cobb angle of 10 degrees or greater in adults [5]. Hyperkyphosis and hyperlordosis are commonly referred to as kyphosis and lordosis by the medical community. The evaluation of these conditions is challenging due to the lack of standardized diagnostic criteria. Generally, the Cobb angle of a normal thoracic spine ranges between 20 and 50 degrees in young people [1 6].

Among community-dwelling individuals ≥ 60 years old, the current incidence of hyperkyphosis is between 20 and 40 percent [7-9]. There are multiple contributing factors to spinal curvature disorders, such as vertebral fractures with low bone density [10-12], short vertebral height as in Scheuermann disease [13], degenerative disc disease [14], postural changes[15-18], muscle weakness[15 19-23], intervertebral ligament degeneration[24], and systemic physical activity practice[25-28].

Injury is an important issue in public health [29], especially among the elderly [30]. Injuries can be divided into several types according to various factors, such as injury diagnosis, cause of injury, or intentionality of injury according to the National Health Insurance Research Database (NHIRD) of Taiwan [31]. The occurrence of injury influences the capacity for activity and can cause complications, economic burden, and even mortality [32-35]. Thus, determining the modifiable risks and strategies for the prevention or management of injury deserves more clinical attention.

The potential relationship between spinal curvature disorders and injury is not precisely known. Sinaki et al. demonstrated that thoracic hyperkyphosis in the context of reduced muscle strength plays an important role in increasing body sway, gait unsteadiness, and risk of falls in osteoporosis [23]. De Groot et al. suggest that patients with flexed posture (characterized by protrusion of the head and increased thoracic kyphosis) have impaired postural control during walking and may therefore have higher risk of falling [36]. However, no study has described the sequential association between spine curvature disorders and injury. We conducted a nationwide population-based cohort study to investigate whether spinal curvature disorders increases the risk of injury.

Materials and Methods

Data sources

Taiwan's NHIRD has been built since Taiwan established a universal health care system in 1995. This database includes the medical records of the Taiwanese population of around 23.81 million, and the coverage reached 99.6% in 2016. In this study, data were collected from the NHIRD, and 1,000,000 people were randomly and anonymously selected from the entire population. The disease diagnosis codes in the NHIRD dossier are based on the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)[37]. This study was approved after a complete ethical review by the Institutional Review Board (IRB) of National Defense Medical Center Tri-Service General Hospital (approval number: TSGHIRB No. 1-105-05-142) and the informed consent was not necessary.

Study design and sampled participants

This study was a retrospective cohort design. Patients were selected if they were diagnosed with spinal curvature disorders with ≥ 3 outpatient visits and spinal curvature disorders inpatients from January 2, 2000, to December 31, 2010, according to the following ICD-9 codes: kyphosis (ICD-9-CM 737.0, 737.1, 737.41), lordosis (ICD-9-CM 737.2, 737.42), kyphoscoliosis and scoliosis (ICD-9-CM 737.3, 737.43), and unspecified (ICD-9-CM 737.40, 737.8, 737.9) from the Longitudinal Health Insurance Database (LHID). Patients were excluded for the following reasons: 1) spinal curvature disorders diagnosed before 2000, 2) injury before tracing, 3) age < 20 years, and 4) unknown gender. The patients were divided into four groups based on the ICD codes.

For the control cohort, we randomly selected patients without spinal curvature disorders in this period from among insured individuals. We excluded control subjects according to the same criteria. The spinal curvature disorders cohort and control cohort were frequency matched by gender, age, and index rate (Figure 1).

Patient and public involvement

This retrospective cohort study used Taiwan National Health Insurance Research Database with anonymized identifications. Therefore, patients and public were not involved.

Outcome measures

All study participants were followed from the index date until the first diagnosis of injury (ICD-9-CM 800–999), withdrawal from the National Health Insurance (NHI) program, or the end of 2010. Based on the definition of injury categories from prior studies [31 38], the causes of injury were classified as traffic injuries (ICD-9-CM E800-E849), poisoning (ICD-9-CM E850-E869), falls (ICD-9-CM E880-E888), burns and fires (ICD-9-CM E890-E899), drowning (ICD-9-CM E910), suffocation (ICD-9-CM E911-E915), crushing/cutting/piercing (ICD-9-CM E916-E920), other unintentional injuries (ICD-9-CM E870-E879, E900-E909, E951-E949). The intentionality categories of injuries include unintentional (ICD-8-CM E800-R949), intentional (ICD-9-CM E950-E979, E990-E999), and unknown.

Comorbidities

Baseline comorbidities include diabetes (ICD-9-CM 250), hypertension (ICD-9-CM 401 – 405), ischemic heart disease (ICD-9-CM codes 410–414), stroke (ICD-9-CM 430-438), chronic kidney disease (ICD-9-CM 585), liver cirrhosis (ICD-9-CM 570, 571, 572.1, 572.4, 573.1–573.3), chronic obstructive lung disease (ICD-9-CM codes 490, 491, 495, and 496), and cancer (ICD-9-CM 140-208). The population was also stratified according to the number of comorbidities (0, 1, and ≥ 2).

Statistical analysis

All analyses were performed using the Statistical Package for the Social Sciences (SPSS) (V.21; SPSS Inc., Chicago, Illinois, USA). Chi squared and t tests were used to evaluate the distributions of categorical and continuous variables between patients with spinal curvature disorders and the control group. The incidence rates of injury were calculated according to gender, age, number of comorbidities, urbanization level, and insurance premium. Multivariable Cox proportional hazards regression models were used to determine the risk of injury, which is presented as a hazard ratio (HR) with a 95% confidence interval (CI). The difference in injury risk between the two groups was estimated using the Kaplan-Meier method with the log-rank test. A two-tailed p value < 0.05 was considered significant.

Results

We enrolled 20,566 patients who had spinal curvature disorders and 41,132 subjects without spinal curvature disorders in the control group. The majority of patients were ≥ 65 years old (52.82% and 51.58% for spinal curvature disorders and control group, respectively). Females accounted for more than half of the subjects (64.61%) in each cohort. There is a significant difference in the number of comorbidities, urbanization level, and insurance premium between the spinal curvature group and control group (Table 1). The average period of follow-up was 5.48 years for the spinal curvature disorders cohort and 6.24 years for the control group.

Table 2 shows that the incidence of injury was higher in the spinal curvature disorders cohort than that in the control cohort (10905.25 and 9059.47 incidences per 100,000 person-years, respectively). Compared to the control group, spinal curvature disorders patients were associated with a significantly higher risk of injury (adjusted HR 2.209 (95% CI 2.118 to 2.303)). The spinal curvature disorders cohort exhibited a higher risk of injury compared to the control group, regardless of age, sex, comorbidities, and urbanization level. The risk of injury was also significantly higher in the spinal curvature disorders cohort than in the control cohort among patients with insurance premiums < 18,000 New Taiwan dollars (NTD) and 18,000-34,999 NTD. Table 3 shows the risks of injury stratified by subgroup of spinal curvature disorders (kyphosis, lordosis, kyphoscoliosis and scoliosis, and unspecified type). All subgroups of spinal curvature disorders had a significantly higher risk of injury compared to the control cohort (adjusted HR 2.777 (95% CI 2.553 to 3.021), 2.087 (95% CI 1.235 to 3.527), 2.113 (95% CI 2.021 to 2.210), 2.727 (95% CI 2.119 to 3.509), respectively).

Table 4 shows the incidence and adjusted HR of injury according to the injury diagnosis, cause of injury, and intentionality of injury at the end of the follow-up period. The spinal curvature disorders cohort had a significantly higher risk of unintentionality of injury compared to the control cohort (adjusted HR 1.537 (95% CI 1.200 to 2.605)). The spinal curvature disorders cohort had significantly higher risk in injury diagnoses of fracture, dislocation, open wound, superficial injury/contusion, crushing, injury to nerve and spinal cord, and other injury compared to the control cohort (adjusted HR 1.502 (95% CI 1.398 to 1.614), 1.732 (95% CI 1.172 to 2.558), 1.597 (95% CI 1.310 to 1.939), 1.414 (95% CI 1.131 to 1.761), 4.949 (95% CI 1.093 to 30.895), 2.428 (95% CI 1.310 to 4.500), and 1.387 (95% CI 1.284 to 1.499), respectively). They also had significantly higher risk of traffic injuries, falls, suffocation, crushing/cutting/piercing, and other injuries compared to the control cohort (adjusted HR 1.379 (95% CI 1.191 to 1.597), 1.552 (95% CI 1.429 to 1.686), 6.442 (95% CI 2.335 to 17.776), 2.595 (95% CI 1.056 to 3.409), and 1.612 (95% CI 1.443 to 1.800), respectively). Significantly higher risk of unintentional injury was also observed in the spinal curvature disorders cohort (1.537 (95% CI 1.200 to 2.605)).

We used Kaplan-Meier survival analysis to assess the cumulative incidence. The injury rates of spinal curvature disorders subjects (17.59 %, in 20,566) and non-spinal curvature disorders control (15.20%, in 41,132), and in two-tailed test, while setting the significance as $p < 0.05$, the estimated statistical power for this study is 0.999. There were significant differences in the cumulative incidence of injury among the patients with and without spinal curvature disorders from the 1st to the 11th follow-up year (log-rank test; $p < 0.001$) (Figure 2).

Discussion

This is the first nationwide population-based cohort study to investigate the associations between spinal curvature disorders and injury. We found that patients with spinal curvature disorders had 2.209-times higher risk of developing injury compared to those without spinal curvature disorders. Although the spinal curvature disorders and non-spinal curvature disorders cohorts had different prevalence of comorbidities, urbanization level, and insurance premium on the index day, spinal curvature disorders remained an independent risk factor for injury in the adjusted Cox regression analysis. As shown in Table 2, patients in the spinal curvature disorders cohort had a higher incidence of injury than patients in the control cohort in most of the subgroup analyses of sex, age, comorbidity, urbanization level and socioeconomic status. This observation strengthens the finding that spinal curvature disorders independently increases the risk of injury.

For subgroup analysis of injury events, we found that patients with spinal curvature disorders had higher risk of unintentional injury and injury diagnoses such as fracture, dislocation, open wound, superficial injury/contusion, crushing, and injury to nerves and spinal cord. The severity of spinal curvature disorders is defined by the measurement of the Cobb angle of curvature [3]. Chest wall compliance decreases in severe cases, which leads to difficulty in breathing, increased risk of respiratory muscle fatigue [39 40], increased dead space fraction, alveolar hypoventilation with hypercapnia [41], hypoxemia [42], ventilation-perfusion mismatch, apneic events with nocturnal hypoventilation and arterial oxygen desaturation [39 43], and exercise limitations [44 45]. Previous studies also suggest that spinal curvature disorders is associated with reduced muscle strength, increased body sway, and gait unsteadiness [23 46-48]. The increased risk of unintentional injury in our study may be explained by these systemic manifestations of spinal curvature disorders.

We found that patients with spinal curvature disorders had higher risks of various injury causes, such as traffic injuries, falls, suffocation, crushing/cutting/piercing, and other unintentional injuries. Among these causes, risk of suffocation (adjusted HR 6.442) was much higher than that of other injuries. Although respiratory muscle fatigue[15 16] and lung function impairment were found in patients with spinal curvature[17], there are insufficient studies explaining the mechanism between spinal curvature disorders and suffocation. Further studies for analyzing this correlation are warranted.

After stratifying patients with injury by age, we found that the adjusted HR of subjects aged 20 to 40 years and 41 to 64 years were much higher than in those aged 65 years and above (adjusted HR: 6.665, 6.154, and 1.666, respectively). This contrasts with the concept that risk of injury is higher among the elderly, especially for fracture due to car crashes [49]. The actual mechanisms remain unknown for this phenomenon. We found that older patients with spinal curvature disorders had more comorbidities than younger patients with these disorders (Table 2). Previous studies showed that age and chronic illness are associated with disability in daily living activities [50 51]. Therefore, older patients with spinal curvature disorders may present less activity. On the other hand, previous studies also demonstrated that impaired balance control [52] and changes in the capacity of maintaining position [53] can be found in young scoliosis patients. It is possible that daily activities may be less limited in younger populations with spinal curvature disorders, which increases the risk of injury. Future studies on this correlation are warranted.

The treatment of spinal curvature disorders includes supportive care, bracing, pulmonary rehabilitation, noninvasive ventilation, and surgery [54-58]. Treatment may also improve pulmonary function, exercise capacity, and arterial blood gas, as well as eliminate obstructive apnea [59]. We found spinal curvature disorders were associated with higher risk of injury. However, whether providing assistive devices or protective gear to patients with spinal curvature disorders decreases the incidence of injury remains uncertain. Future studies focusing on the association between early detection, adequate treatment of spinal curvature disorders, and the prevention of injury are warranted.

This study has some limitations. Firstly, the severity of spinal curvature disorders, the subjective symptoms and physical examinations were not recorded which might confound the incidence rate of spinal curvature disorders. Secondly, there is no information on patient characteristics from the NHIRD. The data lacked information about smoking, dietary habits, alcoholism, substance use, obesity and bone mineral density, which might influence the time and incidence rate of injury occurrence. Thirdly, the severity of injuries that would impact the patient's daily life was not evaluated. Fourthly, other bias might remain in this retrospective cohort study, despite the meticulous adjustment of the model for potential confounders.

In conclusion, our study suggests that patient with spinal curvature disorders exhibit higher risk of developing injury than patients without spinal curvature disorders, especially the risks of unintentional injury and injury diagnoses such as fracture, dislocation, open wound, superficial injury/contusion, crushing, and injury to nerves and spinal cord. Aggressive detection and management of patients with spinal curvature disorders may be beneficial for injury prevention from a public health perspective.

Reference

1. Fon GT, Pitt MJ, Thies AC, Jr. Thoracic kyphosis: range in normal subjects. *AJR Am J Roentgenol* 1980;134(5):979-83. doi: 10.2214/ajr.134.5.979
2. Voutsinas SA, MacEwen GD. Sagittal profiles of the spine. *Clin Orthop Relat Res* 1986(210):235-42.

3. J. C. Outline for the study of scoliosis. *Amer Acad Orthop Surg Instructional Course Lectures* 1948;5:261–75.

4. Vasiliadis ES, Grivas TB, Kaspiris A. Historical overview of spinal deformities in ancient Greece. *Scoliosis* 2009;4:6. doi: 10.1186/1748-7161-4-6

5. Kane WJ. Scoliosis prevalence: a call for a statement of terms. *Clin Orthop Relat Res* 1977(126):43-6.

6. Boseker EH, Moe JH, Winter RB, et al. Determination of "normal" thoracic kyphosis: a roentgenographic study of 121 "normal" children. *J Pediatr Orthop* 2000;20(6):796-8.

7. Kado DM, Huang MH, Karlamangla AS, et al. Hyperkyphotic posture predicts mortality in older community-dwelling men and women: a prospective study. *J Am Geriatr Soc* 2004;52(10):1662-7. doi: 10.1111/j.1532-5415.2004.52458.x

8. Ryan SD, Fried LP. The impact of kyphosis on daily functioning. *J Am Geriatr Soc* 1997;45(12):1479-86.

9. Takahashi T, Ishida K, Hirose D, et al. Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. *Osteoporos Int* 2005;16(3):273-9. doi: 10.1007/s00198-004-1669-3

10. Ensrud KE, Black DM, Harris F, et al. Correlates of kyphosis in older women. The Fracture Intervention Trial Research Group. *J Am Geriatr Soc* 1997;45(6):682-7.

11. Kado DM, Huang MH, Karlamangla AS, et al. Factors associated with kyphosis progression in older women: 15 years' experience in the study of osteoporotic fractures. *J Bone Miner Res* 2013;28(1):179-87. doi: 10.1002/jbmr.1728

12. Pavlovic A, Nichols DL, Sanborn CF, et al. Relationship of thoracic kyphosis and lumbar lordosis to bone mineral density in women. *Osteoporos Int* 2013;24(8):2269-73. doi: 10.1007/s00198-013-2296-7

13. Axenovich TI, Zaidman AM, Zorkoltseva IV, et al. Segregation analysis of Scheuermann disease in ninety families from Siberia. *Am J Med Genet* 2001;100(4):275-9.

14. Schneider DL, von Muhlen D, Barrett-Connor E, et al. Kyphosis does not equal vertebral fractures: the Rancho Bernardo study. *J Rheumatol* 2004;31(4):747-52.

15. Kado DM, Prenovost K, Crandall C. Narrative review: hyperkyphosis in older persons. *Ann Intern Med* 2007;147(5):330-8.

16. Boyle JJ, Milne N, Singer KP. Influence of age on cervicothoracic spinal curvature: an ex vivo radiographic survey. *Clin Biomech (Bristol, Avon)* 2002;17(5):361-7.

17. Vialle R, Levassor N, Rillardon L, et al. Radiographic analysis of the sagittal

alignment and balance of the spine in asymptomatic subjects. *J Bone Joint Surg Am* 2005;87(2):260-7. doi: 10.2106/JBJS.D.02043

18. Hinman MR. Comparison of thoracic kyphosis and postural stiffness in younger and older women. *Spine J* 2004;4(4):413-7. doi: 10.1016/j.spinee.2004.01.002
19. Mika A, Unnithan VB, Mika P. Differences in thoracic kyphosis and in back muscle strength in women with bone loss due to osteoporosis. *Spine (Phila Pa 1976)* 2005;30(2):241-6.
20. Brocklehurst JC, Robertson D, James-Groom P. Skeletal deformities in the elderly and their effect on postural sway. *J Am Geriatr Soc* 1982;30(8):534-8.
21. Chow RK, Harrison JE. Relationship of kyphosis to physical fitness and bone mass on post-menopausal women. *Am J Phys Med* 1987;66(5):219-27.
22. Sinaki M, Itoi E, Rogers JW, et al. Correlation of back extensor strength with thoracic kyphosis and lumbar lordosis in estrogen-deficient women. *Am J Phys Med Rehabil* 1996;75(5):370-4.
23. Sinaki M, Brey RH, Hughes CA, et al. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. *Osteoporos Int* 2005;16(8):1004-10. doi: 10.1007/s00198-004-1791-2
24. Birnbaum K, Siebert CH, Hinkelmann J, et al. Correction of kyphotic deformity before and after transection of the anterior longitudinal ligament--a cadaver study. *Arch Orthop Trauma Surg* 2001;121(3):142-7.
25. Esparza FV-C, Raquel & Alacid, Fernando & Martínez-Ruiz, E & López-Miñarro, Pedro. Sagittal spinal curvatures in maximal trunk flexion of young female dancers. *British journal of sports medicine* 2014;48.:595. doi: 10.1136/bjsports-2014-093494.95.
26. López-Miñarro PM, José & Alacid, Fernando & Manuel, Isorna & Vaquero-Cristóbal, Raquel. Sagittal spinal curvatures and pelvic inclination in kayakers. *Revista Internacional de Medicina y Ciencias de la Actividad Fisica y del Deporte* 2014;14.:633-50. .
27. Vaquero-Cristóbal RE, Francisco & Gómez-Durán, R & Martínez-Ruiz, E & Muyor, José & Alacid, Fernando & López-Miñarro, Pedro. Thoracic and lumbar morphology in standing, sitting and maximal trunk flexion with extended knees in dancers. *Archivos de Medicina del Deporte* 2015;32.:87-93.
28. López-Miñarro PA, Muyor JM. Comparison of sagittal spinal curvatures and pelvic tilt in highly trained athletes from different sport disciplines. *Kinesiology* 2017;49(1):109-16. doi: 10.26582/k.49.1.2
29. Haagsma JA, Graetz N, Bolliger I, et al. The global burden of injury: incidence, mortality, disability-adjusted life years and time trends from the Global

Burden of Disease study 2013. *Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention* 2016;22(1):3-18. doi: 10.1136/injuryprev-2015-041616

30. Yeo YY, Lee SK, Lim CY, et al. A review of elderly injuries seen in a Singapore emergency department. *Singapore Med J* 2009;50(3):278-83.
31. Chien WC, Chung CH, Lai CH, et al. A retrospective population-based study of injury types among elderly in Taiwan. *International journal of injury control and safety promotion* 2014;21(1):3-8. doi: 10.1080/17457300.2012.717084 [published Online First: 2012/08/29]
32. National estimates of the ten leading causes of nonfatal injuries, Centers for Disease Control and Prevention. *CDC* 2004;www.cdc.gov/injury/wisqars.html (Accessed on May 24, 2010).
33. Mackenzie EJ, Rivara FP, Jurkovich GJ, et al. The National Study on Costs and Outcomes of Trauma. *J Trauma* 2007;63(6 Suppl):S54-67; discussion S81-6. doi: 10.1097/TA.0b013e31815acb09
34. Global burden of disease. *World Health Organization* 2010; www.who.int/healthinfo/global_burden_disease/en/ (Accessed on May 01, 2010).
35. Global Status on Road Safety. *World Health Organization* 2015;http://www.who.int/violence_injury_prevention/road_safety_status/2015/ (Accessed on April 04, 2016).
36. de Groot MH, van der Jagt-Willems HC, van Campen JP, et al. A flexed posture in elderly patients is associated with impairments in postural control during walking. *Gait Posture* 2014;39(2):767-72. doi: 10.1016/j.gaitpost.2013.10.015
37. Organization GWH. World Health Organization, Manual of the International Classification of Diseases, Injuries, and Causes of Death, Ninth Revision. 1977
38. Lin CL, Chung CH, Tsai YH, et al. Association between sleep disorders and injury: a nationwide population-based retrospective cohort study. *Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention* 2016;22(5):342-6. doi: 10.1136/injuryprev-2015-041844 [published Online First: 2016/02/20]
39. Jones RS, Kennedy JD, Hasham F, et al. Mechanical inefficiency of the thoracic cage in scoliosis. *Thorax* 1981;36(6):456-61.
40. Di Bari M, Chiarlone M, Matteuzzi D, et al. Thoracic kyphosis and ventilatory dysfunction in unselected older persons: an epidemiological study in Dicomano, Italy. *J Am Geriatr Soc* 2004;52(6):909-15. doi: 10.1111/j.1532-5415.2004.52257.x
41. Bergofsky EH, Turino GM, Fishman AP. Cardiorespiratory failure in kyphoscoliosis.

Medicine (Baltimore) 1959;38:263-317.
42. Naeye RL. Kyphoscoliosis and cor pulmonale; a study of the pulmonary vascular bed. *Am J Pathol* 1961;38:561-73.
43. Shannon DC, Riseborough EJ, Kazemi H. Ventilation perfusion relationships following correction of kyphoscoliosis. *JAMA* 1971;217(5):579-84.
44. Shneerson JM. The cardiorespiratory response to exercise in thoracic scoliosis. *Thorax* 1978;33(4):457-63.
45. Kesten S, Garfinkel SK, Wright T, et al. Impaired exercise capacity in adults with moderate scoliosis. *Chest* 1991;99(3):663-6.
46. Lynn SG, Sinaki M, Westerlind KC. Balance characteristics of persons with osteoporosis. *Arch Phys Med Rehabil* 1997;78(3):273-7.
47. de Groot MH, van der Jagt-Willems HC, van Campen JP, et al. Testing postural control among various osteoporotic patient groups: a literature review. *Geriatr Gerontol Int* 2012;12(4):573-85. doi: 10.1111/j.1447-0594.2012.00856.x
48. Katzman WB, Vittinghoff E, Kado DM, et al. Thoracic kyphosis and rate of incident vertebral fractures: the Fracture Intervention Trial. *Osteoporos Int* 2016;27(3):899-903. doi: 10.1007/s00198-015-3478-2
49. Brorsson B. Age and injury severity. *Scand J Soc Med* 1989;17(4):287-90.
50. Wu SC, Leu SY, Li CY. Incidence of and predictors for chronic disability in activities of daily living among older people in Taiwan. *J Am Geriatr Soc* 1999;47(9):1082-6.
51. Covinsky KE, Palmer RM, Fortinsky RH, et al. Loss of independence in activities of daily living in older adults hospitalized with medical illnesses: increased vulnerability with age. *J Am Geriatr Soc* 2003;51(4):451-8.
52. Gauchard GC, Lascombes P, Kuhnast M, et al. Influence of different types of progressive idiopathic scoliosis on static and dynamic postural control. *Spine (Phila Pa 1976)* 2001;26(9):1052-8.
53. Silferi V, Rougier P, Labelle H, et al. [Postural control in idiopathic scoliosis: comparison between healthy and scoliotic subjects]. *Rev Chir Orthop Reparatrice Appar Mot* 2004;90(3):215-25.
54. Skaggs DL, Bassett GS. Adolescent idiopathic scoliosis: an update. *Am Fam Physician* 1996;53(7):2327-35.
55. Weinstein SL, Dolan LA, Wright JG, et al. Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med* 2013;369(16):1512-21. doi: 10.1056/NEJMoa1307337
56. Negrini S, Minozzi S, Bettany-Saltikov J, et al. Braces for idiopathic scoliosis in adolescents. *Cochrane Database Syst Rev* 2015(6):CD006850. doi:

10.1002/14651858.CD006850.pub3

57. Fuschillo S, De Felice A, Martucci M, et al. Pulmonary rehabilitation improves exercise capacity in subjects with kyphoscoliosis and severe respiratory impairment. *Respir Care* 2015;60(1):96-101. doi: 10.4187/respcare.03095

58. Obayashi H, Urabe Y, Yamanaka Y, et al. Effects of respiratory-muscle exercise on spinal curvature. *J Sport Rehabil* 2012;21(1):63-8.

59. Menon B, Aggarwal B. Influence of spinal deformity on pulmonary function, arterial blood gas values, and exercise capacity in thoracic kyphoscoliosis. *Neurosciences (Riyadh)* 2007;12(4):293-8.

Figure Legends

Figure 1. The flowchart of study sample selection from Taiwan National Health Insurance Research Database

Figure 2. Kaplan-Meier curve for cumulative risk of injury among aged 20 over stratified by spinal curvature disorders with log-rank test

Table 1. Demographic data for patients with and without spinal curvature disorders

	Spinal curvature disorders				*p value*
	with		without		
Variables	n	%	n	%	
Total	20,566	33.33	41,132	66.67	
Gender					0.999

Male	7,279	35.39	14,558	35.39	
Female	13,287	64.61	26,574	64.61	
Age group (years)					0.999
20-40	3,107	15.11	6,529	15.87	
41-64	6,597	32.08	13,386	32.54	
≧65	10,862	52.82	21,217	51.58	
Number of comorbidities					<0.001
0	12,469	60.63	19,513	47.44	
1	6,074	29.53	12,021	29.23	
≧2	2,023	9.84	9,598	23.33	
Urbanization level					<0.001
1 (The highest)	8,147	39.61	14,344	34.87	
2	7,807	37.96	17,780	43.23	
3	2,021	9.83	2,946	7.16	
4 (The lowest)	2,591	12.60	6,062	14.74	
Insurance premium (NT$)					<0.001
<18,000	20,193	98.19	40,541	98.56	
18,000-34,999	324	1.58	482	1.17	
≧35,000	49	0.24	109	0.27	

Table 2. Risk of injury stratified by variables

	With spinal curvature disorders			Without spinal curvature disorders			Ratio	Adjusted HR†(95%CI)
Variables	**Event**	**PYs**	**IR‡ (per 10^5 PYs)**	**Event**	**PYs**	**IR‡ (per 10^5 PYs)**		
Total	3,617	33,167.52	10,905.25	6,254	69,032.77	9,059.47	1.204	2.209 (2.118-2.303) *
Gender								
Male	1,308	12,003.99	10,896.38	2,288	24,100.91	9,493.42	1.148	2.098 (1.958-2.249) *
Female	2,309	21,163.52	10,910.28	3,966	44,931.86	8,826.70	1.236	2.279 (2.162-2.402) *
Age group (years)								

20-40	289	2,945.11	9,812.88	177	6,082.11	2,910.17	3.372	6.665 (5.512-8.060) *
41-64	885	7,561.59	11,703.89	603	8,360.88	7,212.16	1.623	6.154 (5.527-6.852) *
≧65	2,443	22,660.82	10,780.72	5,474	54,589.78	10,027.52	1.075	1.666 (1.587-1.749) *
Number of comorbidities								
0	2,008	14,400.78	13,943.69	2,653	22,738.69	11,667.34	1.195	2.424 (2.284-2.572) *
1	1,142	11,337.55	10,072.72	2,077	21,977.53	9,450.56	1.066	2.203 (2.047-2.371) *
≧2	467	7,429.19	6,286.02	1,524	24,316.54	6,267.34	1.003	1.674 (1.507-1.860) *
Urbanization level								
1 (The highest)	1,012	9,790.98	10,336.04	1,759	20,803.62	8,455.26	1.222	2.225 (2.056-2.409) *
2	1,522	14,516.01	10,484.97	2,813	31,263.20	8,997.80	1.165	2.145 (2.012-2.285) *
3	325	2,422.89	13,413.73	463	4,925.73	9,399.62	1.427	2.766 (2.390-3.202) *
4 (The lowest)	758	6,437.64	11,774.50	1,219	12,040.22	10,124.40	1.163	2.131 (1.942-2.339) *
Insurance premium (NT$)								
<18,000	3,545	32,458.79	10,921.54	6,161	67,962.43	9,065.30	1.205	2.210 (2.118-2.305) *
18,000-34,999	68	643.84	10,561.63	88	965.58	9,113.69	1.159	2.297 (1.651-3.194) *
≧35,000	4	64.89	6,164.28	5	104.76	4,772.81	1.292	1.868 (0.430-8.119) **

*p<0.001; **p=0.405

†Adjusted HR: multivariable analysis including gender, age, number of comorbidities, urbanization level, and insurance premium.

‡Indicates incidence rate per 100,000 person-years.

IR, incidence rate; PYs = Person-years; Adjusted HR = Adjusted Hazard ratio; CI = confidence interval

Table 3. Risk of injury stratified by subgroup of spinal curvature disorders

Spinal curvature disorders	Crude HR (95% CI)	Adjusted HR † (95%CI)
Kyphosis		
With	1.579	2.777 (2.553 - 3.021) *
Without	1 (Reference)	1 (Reference)
Lordosis		
With	1.033	2.087 (1.235 - 3.527) **
Without	1 (Reference)	1 (Reference)
Kyphoscoliosis and scoliosis		

With	1.146	2.113(2.201 - 2.210) *
Without	1 (Reference)	1 (Reference)
Unspecified		
With	1.388	2.727(2.119 - 3.509) *
Without	1 (Reference)	1 (Reference)

ICD-9-CM code: kyphosis (ICD-9-CM 737.0, 737.1, 737.41), lordosis (ICD-9-CM 737.2, 737.42), kyphoscoliosis and scoliosis (ICD-9-CM 737.3, 737.43), and unspecified (ICD-9-CM 737.40, 737.8, 737.9)

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification

*p< 0.001

**p=0.006

†Adjusted HR: multivariable analysis including gender, age, comorbidities, urbanization level, and insurance premium.

Adjusted HR = Adjusted Hazard ratio; CI = confidence interval

Table 4. Risk of injury stratified by injury diagnosis, cause of injury, and intentionality of injury in the end of follow-up

	Crude HR (95%CI)	Adjusted HR † (95%CI)
Injury diagnosis		
Fracture	1.193	1.502 (1.398-1.614) *
Dislocation	1.859	1.732 (1.172-2.558) *
Sprains and strains	1.510	1.341 (0.927-1.942)
Intracranial/internal injury	0.835	0.996 (0.808-1.501)
Open wound	1.244	1.597 (1.310-1.939) *

Injury to blood vessels	0.297	0.287 (0.007-11.122)
Superficial injury/contusion	1.321	1.414 (1.131-1.761) *
Crushing	4.460	4.949 (1.093-30.895) *
Foreign body entering through orifice	1.469	1.921 (0.970-3.803)
Burn	2.018	1.453 (0.968-2.180)
Injury to nerves and spinal cord	2.379	2.428 (1.310-4.500) *
Poisoning	0.999	0.983 (0.809-1.602)
Others injury	1.270	1.387 (1.284-1.499) *
Cause of injury		
Traffic injuries	1.370	1.379 (1.191-1.597) *
Poisoning	1.150	1.423 (0.906-2.234)
Falls	1.258	1.552 (1.429-1.686) *
Burns and fires	2.498	1.567 (0.977-2.567)
Drowning	N/A	N/A
Suffocation	1.972	6.442 (2.335-17.776) *
Crushing/cutting/piercing	1.788	2.595 (1.056-3.409) *
Other injuries	1.401	1.612 (1.443-1.800) *
Intentionality of injury		

Unitentional	1.335	1.537 (1.200-2.605) *
Intentional	2.330	2.218 (0.994-3.424)
Unknown	1.095	1.076 (0.419-1.830)

*p<0.05

Some patients did not provide information about cause and intentionality of injury

†Adjusted HR: multivariable analysis including gender, age, comorbidities, urbanization level, and insurance premium.

Adjusted HR = Adjusted Hazard ratio; CI = confidence interval

N/A: non-applicable due to only one drowning event in spine curvature disorders patients and no drowning event in the control group.

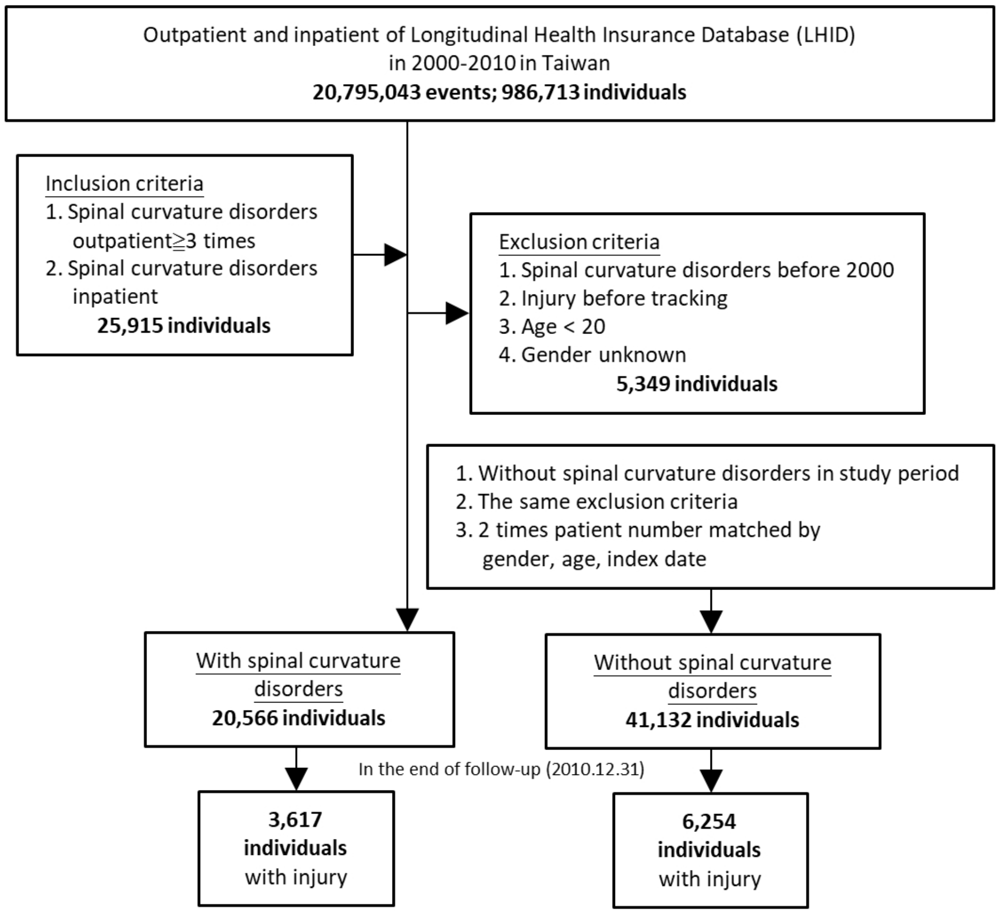

Figure 1. The flowchart of study sample selection from Taiwan National Health Insurance Research Database

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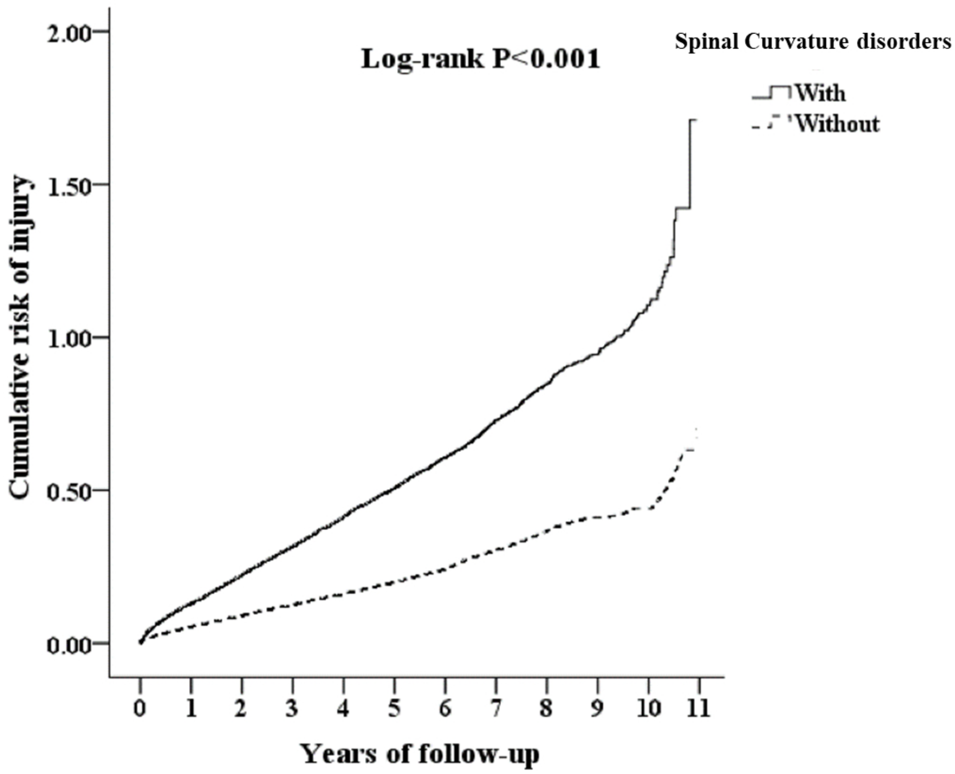

Figure 2. Kaplan-Meier curve for cumulative risk of injury among aged 20 over stratified by spinal curvature disorders with log-rank test

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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract P.1 Title and P.3 Abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found P.3-P.4 Abstract
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported P.7
Objectives	3	State specific objectives, including any prespecified hypotheses P.8
Methods		
Study design	4	Present key elements of study design early in the paper P.9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection P.10
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up P.9 and P.10
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed P.9 and P.10
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable P.10 and P.11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group P.9 and P.10
Bias	9	Describe any efforts to address potential sources of bias P.17 and P.18
Study size	10	Explain how the study size was arrived at P.9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why N/A
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding P.11
		(*b*) Describe any methods used to examine subgroups and interactions P.11
		(*c*) Explain how missing data were addressed N/A
		(*d*) If applicable, explain how loss to follow-up was addressed N/A
		(*e*) Describe any sensitivity analyses N/A
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed P.9 and P.10
		(b) Give reasons for non-participation at each stage P.9 and P.10
		(c) Consider use of a flow diagram P.9 and P.10 and Figure 1.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders P.11 and P.12 and Table 1.
		(b) Indicate number of participants with missing data for each variable of interest N/A
		(c) Summarise follow-up time (eg, average and total amount) P.12
Outcome data	15*	Report numbers of outcome events or summary measures over time P.12-P.14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

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		adjusted for and why they were included P.12
		(*b*) Report category boundaries when continuous variables were categorized P.12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses P.12 to P.14
Discussion		
Key results	18	Summarise key results with reference to study objectives P.14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias P.17 and P.18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence P.17 and P.18
Generalisability	21	Discuss the generalisability (external validity) of the study results P. 17
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based N/A P.6

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