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Review Article

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# Epidemiology of Traumatic and Non-Traumatic Spinal Cord Injury in Korea: A Narrative Review

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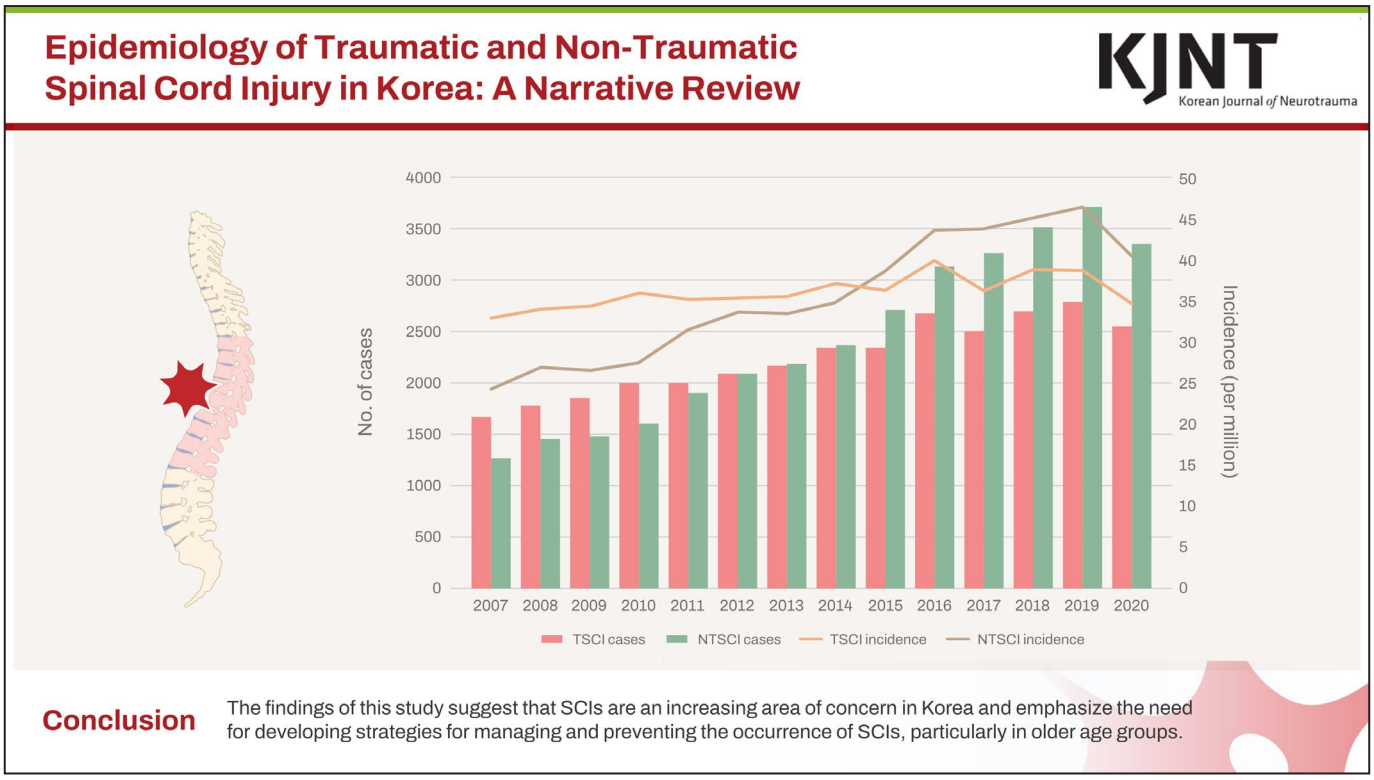
## ABSTRACT

This review describes the incidence rates and trends of traumatic spinal cord injuries (TSCI) and non-traumatic spinal cord injuries (NTSCI) in South Korea. The incidence of NTSCI has increased more rapidly than that of TSCI in recent years. In 2007, TSCI was more common, but by 2020, NTSCI had surpassed TSCI, particularly in older individuals. While men have a higher incidence of both TSCI and NTSCI, the incidence difference by sex is greater in TSCI. The incidence rates of both TSCI and NTSCI are higher in older individuals, particularly those in their 70s and 80s. For TSCI, falls and traffic accidents are the most common causes, with falls being more prevalent in older adults. Cervical SCIs are the most common TSCI, especially in high-income countries like South Korea. Patients with NTSCI predominantly display paraplegia, which is usually associated with non-traumatic causes such as degenerative disorders and tumors. Higher rates of tetraplegia and paraplegia are observed with TSCI and NTSCI, respectively. The neurological levels of injury also differ between TSCI and NTSCI. Overall, SCIs are a growing concern in South Korea and there is a need for targeted interventions for their management and prevention, especially in older age groups.

**Keywords:** Spinal cord injuries; Incidence; Epidemiology; Complications

## GRAPHICAL ABSTRACT




## INTRODUCTION

A spinal cord injury (SCI) is characterized by damage to any part of the spinal cord or the nerves at the end of the spinal canal, along with concurrent injuries to nerve roots, bone structures, and disc-ligament elements.[3,4]

From a clinical perspective, SCIs can be sorted based on various criteria such as the location and severity of the damage, and can be generally divided into traumatic and non-traumatic injuries.[4,9] Traumatic injuries mainly occur due to vehicular crashes, workplace incidents, and falls, while non-traumatic SCIs have a wider range of causes such as degenerative disorders, congenital or hereditary diseases, benign or malignant tumors, vascular disease, infection, and inflammation.[20]

In Korea, national-level analyses for the incidence of SCIs have been performed relatively recently; however, a comprehensive review encompassing both traumatic and non-traumatic SCIs has not yet been conducted.[6,7] This review aimed to summarize the published incidence rates and trends of traumatic spinal cord injury (TSCI) and non-traumatic spinal cord injury (NTSCI) within Korea, and to compare the differences in the incidence rates between the two conditions, in order to gain an overarching understanding of the trends in SCIs across the country.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## EPIDEMIOLOGY OF TSCI AND NTSCI

### Global incidence of TSCI and NTSCI

SCI is a growing global health priority. Many previous studies have attempted to estimate the global incidence of SCI. In 2010, Chiu et al.[4] reported that the incidence of TSCI ranged from 13.1 to 52.2 per million in developed countries and 12.7 to 29.7 per million in developing countries. In 2011, Cripps et al.[9] revealed that the incidence of TSCI was 39 per million in North America, 15 per million in Western Europe, and 16 per million in Australia. Moreover, in 2014, Fitzharris et al.[13] estimated that the global incidence of TSCI in 2007 was 23 per million. In the same year (2014), Lee et al.[25] also reported the global incidence of TSCI in World Health Organization (WHO) regions; North America, 40 per million; Western Europe, 16 per million; Australia, 15 per million; Asia-Central, 25 per million; Asia-South, 21 per million; Caribbean, 19 per million; Latin America, Andean, 19 per million; Latin America, Central, 24 per million; Latin America-Southern, 25 per million; Sub-Saharan Africa-Central, 29 per million; Sub-Saharan Africa-East, 21 per million. In a systematic review published by Kumar et al.[24] in 2018, the global incidence of TSCI was 10.5 per 100,000, with an estimated 768,473 TSCI cases per year. Based on the country classification by income level by the World Bank Country and Lending Groups, the incidence of TSCI in low- and middle-income countries was 13.7 per 100,000, while the incidence in high-income countries was 8.7 per 100,000. Compared to TSCI, the literature on the global incidence of NTSCI is relatively scarce. In 2014, New et al.[33] reported the global incidence of NTSCI in the WHO regions: Asia Pacific, high income countries, 20 per million per year; Australasia, 26 per million per year; Western Europe, median incidence of 6 per million per year; North America, high income countries, median incidence of 76 per million per year; and Oceania, 9 per million per year.

### Incidence of TSCI and NTSCI in South Korea

In South Korea, several previous studies have reported the incidence of TSCI and NTSCI. In a hospital-based study published in 2013, Shin et al.[43] described 538 cases of TSCI in 1987–1996 and 481 cases in 2004–2008. In a population-based study published in 2020, Choi et al.[5] reported an average TSCI incidence of 26.4 per 1 million people in 2007–2017 using the National Health Insurance Service (NHIS) data. A hospital-based study by Lee et al.[26] in 2022 described the number of TSCI cases over the past 30 years by decade, with 688 cases in 1990–1999, 1394 cases in 2000–2009, and 1313 cases in 2010–2019. A population-based study by Bae et al.[1] in 2023 analyzed workers' compensation insurance data and found that the average TSCI incidence was 22.8 per 1 million people injured in occupational accidents in 2010–2019. Our population-based study published in 2023 reported that the incidence of TSCI in 2018 was 38.14 per million based on NHIS data, 11.57 per million based on automobile insurance data, and 28.92 per million based on workers' compensation insurance data.[6] Studies on the incidence of NTSCI in South Korea are also limited compared to studies on TSCI. A hospital-based study by Shin et al.[43] published in 2013 reported 52 patients with NTSCI in 1987–1996 and 481 patients with NTSCI in 2004–2008. A hospital-based study by Lee et al.[27] published in 2022 evaluated the 10-year incidence of NTSCI over the past 30 years and reported 87 patients between 1990–1999, 318 between 2000–2009, and 543 between 2010–2019. In our population-based study published in 2023,[7] the incidence of NTSCI in 2020 was 39.83 per 1 million people based on the NHIS data.

### Annual incidence trends of TSCI and NTSCI

In previous papers, we have reported the incidence of TSCI and NTSCI in Korea using the NHIS data.[6,7] In this study, we compared the incidence of TSCI and NTSCI from 2007 to 2020


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in the NHIS data following the definitions of TSCI and NTSCI used in the previous papers. Briefly, both TSCI and NTSCI were identified according to the International Classification of Diseases, 10th revision (ICD-10). TSCI was defined as inpatients with a TSCI as a primary diagnosis or a vertebral fracture as a primary diagnosis and a TSCI as additional diagnosis. NTSCI was defined as inpatients with a diagnosis of paraplegia, tetraplegia, or cauda equina who had a diagnosis of etiological diseases prior to the paralysis.

The incidence of NTSCI increased more rapidly than that of TSCI in South Korea from 2007 to 2020 (**TABLE 1**).[6,7] The incidence of TSCI increased by 0.87% per year, from 32.27 per million in 2007 to 34.00 per million in 2020, while the incidence of NTSCI increased by 4.93% per year, from 24.11 per million to 39.83 per million during the same period. Notably, in 2007, the number of TSCI cases was higher than the number of NTSCI cases, but by 2020, the number of NTSCI cases exceeded the number of TSCI cases due to a dramatic increase in the incidence of NTSCI.

The difference in the incidence trends of TSCI and NTSCI becomes more pronounced after stratifying by sex (**TABLE 1**). Although men had a higher incidence of both TSCI and NTSCI from 2007 to 2020, the difference in the incidence between men and women was greater for TSCI. As of 2020, the male-to-female ratio for TSCI incidence was 2.8:1, while the male-to-female ratio for NTSCI incidence was 1.5:1.

The incidence of TSCI and NTSCI varies widely from country to country, and even within a country, it depends on the data source of each study. Therefore, we compared the incidence rates of TSCI and NTSCI in other countries by referring to previous studies that used the same data sources and the same study period to estimate the incidence of TSCI and NTSCI. A registry-based study[16] from Norway reported that between 2012 and 2016, the incidence of TSCI increased from 9.1 to 12.4 per million, while the incidence of NTSCI decreased from 7.6 to 5.8 per million person-year.[17] When stratified by sex, both TSCI and NTSCI were more prevalent in men, with a male-to-female ratio of 2.5:1 for TSCI and 2.0:1 for NTSCI in 2016. According to a hospital-based study conducted from 1994 to 2013 in Scotland,[32] the incidence of TSCI increased from 13.3 to 17.0 per million, while the incidence of NTSCI

**TABLE 1.** Annual incidence of traumatic or non-traumatic spinal cord injury (per million) from the National Health Insurance Service database in South Korea

| Year | TSCI | | | | | | NTSCI | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | Men | | Women | | Total | | Men | | Women | |
| | Cases | Age-adjusted incidence† | Cases | Age-adjusted incidence† | Cases | Age-adjusted incidence† | Cases | Age-adjusted incidence† | Cases | Age-adjusted incidence† | Cases | Age-adjusted incidence† |
| 2007 | 1,653 | 32.27 | 1,114 | 45.88 | 539 | 19.48 | 1,254 | 24.11 | 655 | 28.26 | 599 | 20.58 |
| 2008 | 1,763 | 33.34 | 1,182 | 47.58 | 581 | 19.94 | 1,435 | 26.65 | 776 | 31.88 | 659 | 21.83 |
| 2009 | 1,829 | 33.73 | 1,267 | 49.45 | 562 | 19.04 | 1,476 | 26.29 | 799 | 31.94 | 677 | 21.47 |
| 2010 | 1,972 | 35.33 | 1,333 | 50.49 | 639 | 21.27 | 1,588 | 27.19 | 840 | 32.25 | 748 | 22.79 |
| 2011 | 1,974 | 34.51 | 1,398 | 51.56 | 576 | 18.66 | 1,885 | 31.16 | 1,055 | 38.98 | 830 | 24.73 |
| 2012 | 2,073 | 34.83 | 1,413 | 50.33 | 660 | 20.24 | 2,074 | 33.25 | 1,110 | 40.00 | 964 | 27.59 |
| 2013 | 2,140 | 34.83 | 1,492 | 51.47 | 648 | 19.21 | 2,159 | 33.06 | 1,164 | 39.98 | 995 | 27.20 |
| 2014 | 2,316 | 36.45 | 1,525 | 51.16 | 791 | 22.41 | 2,339 | 34.44 | 1,217 | 40.18 | 1,122 | 29.54 |
| 2015 | 2,321 | 35.60 | 1,583 | 51.65 | 738 | 20.52 | 2,682 | 38.28 | 1,526 | 48.84 | 1,156 | 28.75 |
| 2016 | 2,645 | 39.22 | 1,810 | 57.27 | 835 | 22.15 | 3,098 | 43.09 | 1,644 | 50.83 | 1,454 | 36.35 |
| 2017 | 2,476 | 35.53 | 1,731 | 52.80 | 745 | 19.22 | 3,224 | 43.26 | 1,739 | 51.83 | 1,485 | 35.79 |
| 2018 | 2,667 | 38.14 | 1,917 | 58.29 | 750 | 18.87 | 3,473 | 44.53 | 1,869 | 53.45 | 1,604 | 36.98 |
| 2019 | 2,761 | 37.95 | 1,955 | 57.05 | 806 | 19.89 | 3,664 | 45.82 | 1,998 | 56.10 | 1,666 | 36.25 |
| 2020 | 2,521 | 34.00 | 1,784 | 50.72 | 737 | 18.07 | 3,317 | 39.83 | 1,833 | 48.61 | 1,484 | 32.03 |
| APC | | 0.87* | | 1.25* | | −0.17 | | 4.93* | | 4.99* | | 4.74* |

TSCI: traumatic spinal cord injury, NTSCI: non-traumatic spinal cord injury, APC: annual percentage change.
*$p<0.05$. †Age-adjusted incidence using the 2005 standard population of the South Korea.


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decreased from 3.4 to 2.6 per million. After stratifying by sex, both TSCI and NTSCI had a higher incidence in men between 2009 and 2013, with a male-to-female ratio of 2.9:1 for TSCI and 2.5:1 for NTSCI. Overall, the incidence of both TSCI and NTSCI increased in South Korea, with NTSCI increasing more rapidly, while in Norway and Scotland, the incidence of TSCI increased and NTSCI decreased. After stratification by sex, the incidence of both TSCI and NTSCI was higher in men, and the incidence difference by sex was greater for TSCI than for NTSCI in all three countries.

### Increasing incidence in the older population

In South Korea, both TSCI and NTSCI showed the highest incidence in the older population, especially those in their 70s and 80s and older, and NTSCI particularly demonstrated a sharp increase in the incidence in the older age group (**FIGURE 1**).

Regarding the incidence of TSCI, the average age of patients with TSCI was higher in high-income countries than in low-income countries. Globally, the average age of a patient with TSCI is 39.8 years. When categorized by the country income level, the average age of patients with TSCI was the lowest in low-income countries at 36.40 years and the highest in high-income countries at 41.2 years, while it was 38.83 years in middle-income countries.[24] Since South Korea has experienced a steep growth in the national income over the past few decades, previous studies have observed an increase in the average age of patients with TSCI over time. According to a hospital-based study conducted from 1990 to 2019, the mean age of patients

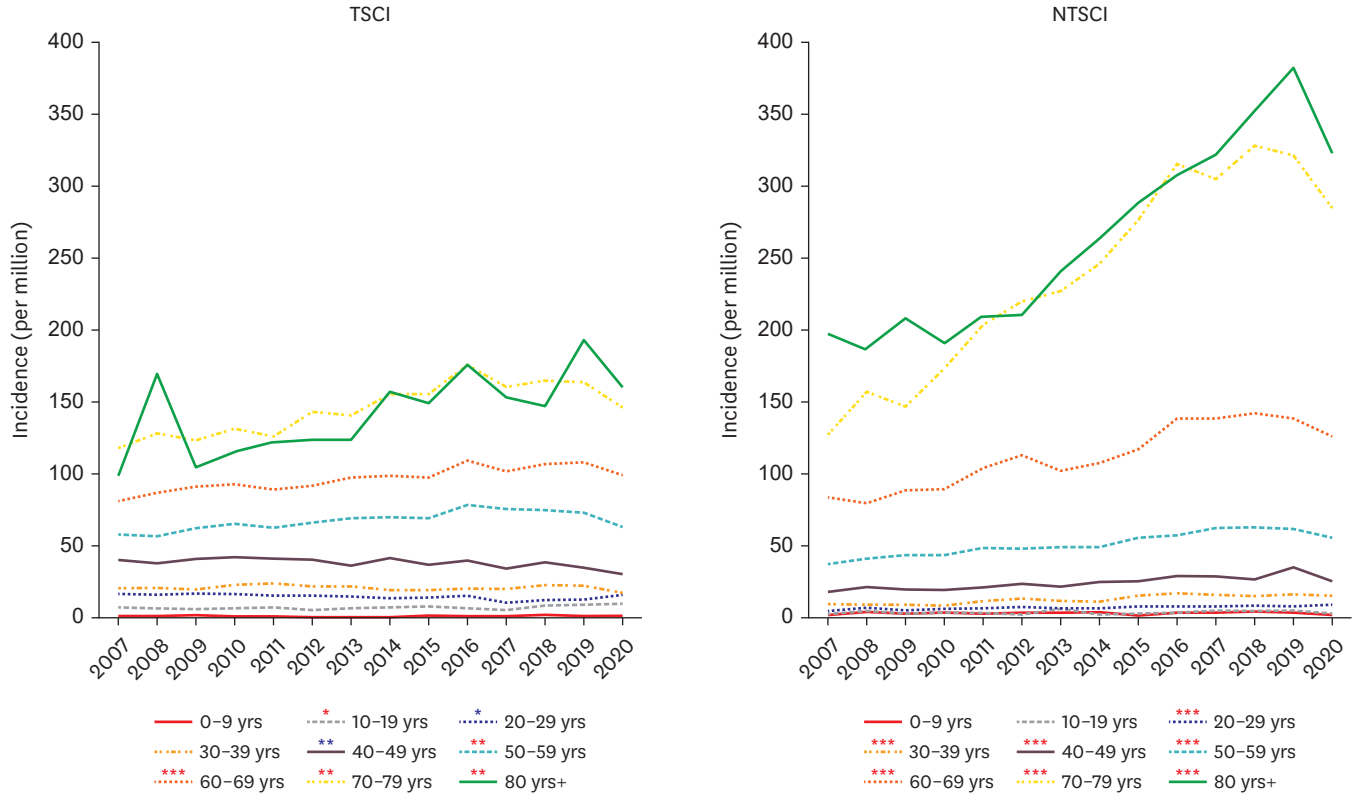


**FIGURE 1.** Incidence of traumatic or non-traumatic spinal cord injury according to age groups from the National Health Insurance Service database in South Korea.
Red asterisk indicates an increasing trend; blue asterisk indicates a decreasing trend.
*$p$ for trend <0.05; **$p$ for trend <0.01; ***$p$ for trend <0.001.


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with TSCI increased from 32.4 years in the 1990s to 47.1 years in the 2010s. Over a 30-year period, the number of patients in the 46–60, 61–75, and 76+ years age groups increased, while the number of patients in the ≤15 and 16–30 years age groups decreased.[26] Another hospital-based study by Shin et al. found that the mean age of the patients with SCI (primarily TSCI) increased from 32.3 to 43.6 years between 1987–1996 and 2004–2008. A significantly higher number of patients was found in the 50+ years age group.[43] Previous studies published in other high-income countries have also reported an increasing incidence of TSCI in older adults. In the United States, a population-based study using a national inpatient sample database found the highest increase in the incidence of acute TSCI in older patients, which was significantly associated with an increase in falls.[21] In Australia, a retrospective cohort study from the Victoria State Trauma Registry demonstrated an increase in the number of TSCI cases among older adults.[3] In addition, an Italian population-based study conducted in 11 regions showed an increased incidence of TSCI in older adults and identified falls as the leading cause of TSCI.[11]

Regarding the high incidence of NTSCI in older adults, previous studies in other high-income countries have reported results that are consistent with our findings. In Norway and Scotland, the highest incidence rates of NTSCI were found in older adults aged 60–74 years and 66–75 years, respectively.[16,17,32] A prospective population-based study in Ireland found the highest age-specific incidence of NTSCI in patients aged 76 years and older.[44] Another population-based study from Victoria, Australia,[39] documented that the age-specific incidence of NTSCI in older adults over 75 years of age was 14 times higher than that in younger patients aged 15 to 24 years. Furthermore, a study from the Canadian province of Manitoba[31] found that older adults aged 61 to 70 years accounted for the highest proportion of patients with NTSCI. Similarly, a multicenter study in Finland[40] reported that the incidence of NTSCI was the highest in older adults aged 60 to 74 years.

## TYPES AND LEVELS OF TSCI AND NTSCI

Among patients with TSCI in South Korea, patients with cervical SCI accounted for more than half of the total, and the proportion of patients with cervical SCI has been gradually increasing over time. In 2007, the proportion of patients with cervical SCI was 52.38%, which increased to 60.93% in 2020 (**FIGURE 2**). Although this high proportion of patients with cervical SCI is a global trend, it is particularly prevalent in high-income countries. In low- and middle-income countries, the proportions of patients with cervical SCI were 39.25% and 41.90%, respectively, while in high-income countries it accounted for 51.41% of the patients.[24] The high proportion of patients with cervical SCI in South Korea may be related to the high proportion of older adults with TSCI. Etiologically, cervical ossification of the ligamentum flavum (COLF) in older adults can be considered a cause of TSCI. Previous meta-analyses have shown that COLF is predominantly found in the older population, especially in East Asian countries.[47] Therefore, underlying COLF in older patients can lead to spinal stenosis,[23] which can cause SCI after a traumatic accident.[6]

A higher proportion of tetraplegia was observed in patients with NTSCI in South Korea in 2007, with tetraplegia occurring in 42.41% patients and paraplegia in 36.55% patients. However, the proportion of patients with tetraplegia gradually decreased and the proportion of patients with paraplegia gradually increased, with tetraplegia occurring in 29.61% and paraplegia in 42.89% patients in 2020 (**FIGURE 2**). Consistent with these findings, Lee et al.[27] reported a high incidence of paraplegia among patients with NTSCI in South Korea. From 1990 to 2019, the incidence of paraplegia among patients with NTSCI was 74.6%, while the incidence of


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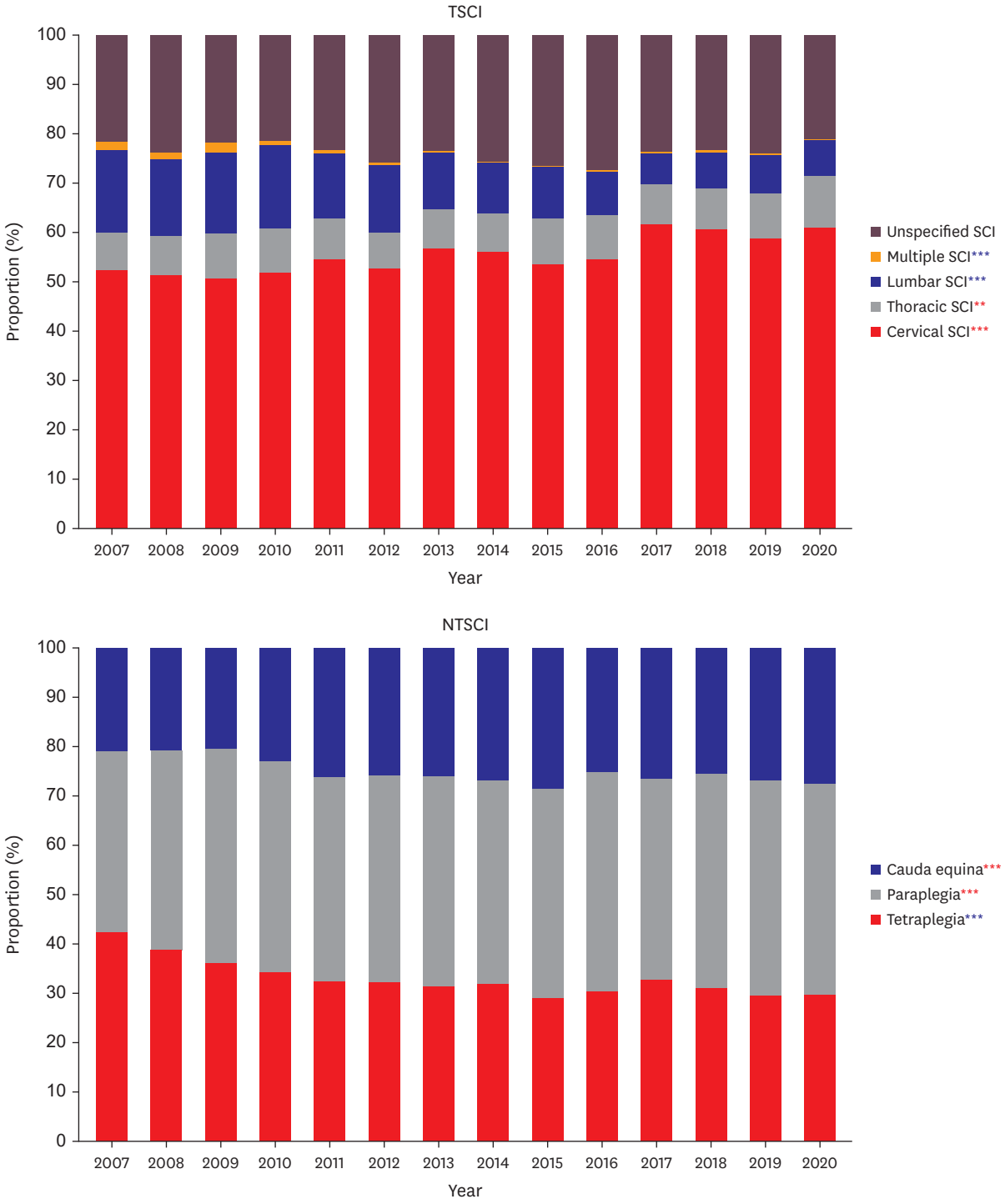


**FIGURE 2.** Types of traumatic or non-traumatic spinal cord injury from the National Health Insurance Service database in South Korea.
Red asterisk indicates an increasing trend; blue asterisk indicates a decreasing trend.
***$p$ for trend <0.001.

tetraplegia was 25.4%. Previous meta-studies have also shown that the incidence of paraplegia was higher in all WHO regions, except for the Asia-Pacific region represented by Japan. [7,33] However, since the Japanese study used in the meta-analysis was based on data from 1988,[18] it is necessary to update the statistics for the Asia-Pacific region using more recent data.[7]


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On comparing the neurological levels of patients with TSCI and NTSCI, the neurological levels of patients with TSCI were C4 (24.0%), C5 (15.3%), C3 (8.2%), C6 (6.5%), and L1 (5.3%), while those of patients with NTSCI were L2 (11.0%), T12 (9.9%), L1 (8.9%), C4 (7.9%), and T9 (7.6%).[27] In addition, the patients with TSCI had the highest proportion of incomplete tetraplegia (37.4%) and the lowest proportion of incomplete paraplegia (16.7%). In contrast, NTSCI patients displayed the highest proportion of incomplete paraplegia (60.9%) and the lowest proportion of complete tetraplegia (2.7%).[27]

## MECHANISMS AND ETIOLOGIES OF SCI

According to the primary mechanism, SCIs can be categorized into TSCI and NTSCI. Generally, TSCIs are caused by traumatic accidents, such as sports accidents, traffic accidents, falls, and assaults.[2,12] In contrast, NTSCIs can result from a variety of non-traumatic causes such as degenerative disorders, congenital or hereditary diseases, benign or malignant tumors, vascular disease, infection, and inflammation.[33,35,37,38]

Globally, traffic accidents and falls are the most important causes of TSCIs (traffic accidents 39.5%, falls 38.8%). In high-income countries, traffic accidents account for 41.6% of TSCIs, compared to 40.7% in middle-income countries and 27.2% in low-income countries.[24] However, falls are the leading cause of TSCIs in regions with large populations of older adults,[25] such as Western Europe, high-income North America, and high-income Asia-Pacific.[14] In South Korea, falls accounted for 56.4% of TSCIs and traffic accidents for 32.6%.[26] In another hospital-based study,[43] although traffic accidents were the leading cause of TSCIs in South Korea, among patients aged 60 years and older, more than half (54.2%) of the TSCIs were caused by falls.

In developed countries, degenerative diseases and tumors tend to be the more prevalent etiologies of NTSCI, while in developing countries, infections, especially tuberculosis and human immunodeficiency virus, are the more prevalent causes of NTSCI, with tumors also often reported as the primary etiology. Degenerative diseases were responsible for the largest proportion of NTSCIs, and the proportion of degenerative diseases as a cause of NTSCIs increased significantly from 55.85% in 2007 to 61.51% in 2020.[7] Lee et al.[27] reported that vertebral column degenerative disorder was the most common cause of NTSCI among patients aged 46 years and older in South Korea. Aging and degenerative diseases are closely related.[7] As individuals age, the spinal cord weakens, and the muscle mass around the spine as well as the spinal bone density decrease.[28] This aging process may lead to degenerative diseases around the spinal cord, such as spondylolisthesis and spinal stenosis, which may contribute to the etiology of NTSCI.[10,19,22,30]

## ACUTE AND CHRONIC COMPLICATIONS OF SCI

During rehabilitation, patients with SCI have been reported to have higher rates of complications than other patients.[15] Previous studies have reported acute and chronic complications of SCI,[45] and these complications may occur individually or in combination as multiple complications.[15] Regardless of TSCI or NTSCI, the most common complication during hospitalization in patients with SCI was urinary tract infection, which accounted for approximately 65%–67% of all complications in patients with TSCI and 42%–50% in those


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with NTSCI.[8,15] In addition, pneumonia, pressure ulcers, and neuropathic pain were common in-hospital complications in patients with SCI, and spasticity, deep venous thrombosis, fluid and electrolyte imbalances, and hypotension were also reported as in-hospital complications in patients with SCI.[8,15,36] The proportion of patients with a combination of 2 or more complications during hospitalization was 53% among patients with TSCI and 31% among patients with NTSCI.[15]

Furthermore, the cardiovascular and psychological complications of SCI may persist for a long time. A longitudinal retrospective cohort study from the United States[41] reported that the 5-year incidence of any cardiometabolic morbidities was 56.2% in patients with SCI and 36.4% in controls without SCI. Patients with SCI showed a higher risk of cardiac dysrhythmias (hazard ratio [HR], 1.35; 95% confidence interval [CI], 1.29–1.41), heart failure (HR, 1.35; 95% CI, 1.28–1.43), and peripheral and visceral atherosclerosis (HR, 1.37; 95% CI, 1.31–1.44) than those without SCI.[41] Psychological complications following SCI have been well documented. A population-based retrospective study[29] using Taiwan's National Health Insurance Research Database demonstrated that patients with TSCI had a 1.29 times higher risk of depression or anxiety compared to those with other health conditions (HR, 1.29; 95% CI, 1.09–1.59). A hospital-based retrospective study from Germany[42] assessed the psychopathology in patients with SCI approximately 4 years post-discharge and reported the following: approximately 46.1% of the patients with TSCI experienced depressive symptoms immediately after hospital discharge, 12.7% developed current depressive disorder, 8.8% of patients with TSCI experienced clinically relevant post-traumatic stress disorder (PTSD) after discharge, and 2% had current chronic PTSD symptomatology. Another cross-sectional study from Turkey[46] found that 33% of patients with TSCI who were at least 3 months post-injury had suicidal ideation over the past 2 weeks, and of the patients with TSCI who experienced suicidal ideation, 71.4% had depression and 52.4% were diagnosed with PTSD.

## CONCLUSIONS

In this study, we have summarized the incidence rates and trends of TSCI and NTSCI in South Korea and compared the differences in the incidence rates between TSCI and NTSCI. Over a period of more than 10 years, there has been an increase in mild injuries within the TSCI group, while the proportion of paraplegia and cauda equina syndrome has been increasing among patients with NTSCI. According to sex, there was a statistically significant increase in the incidence of TSCI among men with an annual percentage change of 1.25%. In contrast, both men and women showed an increase in the incidence of NTSCI, with annual percentage changes of 4.99% and 4.74% among men and women, respectively. The incidence of NTSCI among individuals aged 70 years and above has dramatically increased, reaching twice the incidence rate of TSCI based on data from 2020.

The findings of this study suggest that SCIs are an increasing area of concern in Korea and emphasize the need for developing strategies for managing and preventing the occurrence of SCIs, particularly in older age groups.


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