Review

Thoracic Spinal Injuries in Adolescents: A Narrative Review

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Thoracic Spinal Injuries in Adolescents: A Narrative Review

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Abstract: Despite their increasing prevalence epidemiological data on thoracic spine injuries (TSI) is under-presented in the literature. Furthermore, these studies fail to correlate mechanisms of injury to the specific spinal regions injured. Team ball sports appear to be common activities undertaken in these age groups. A narrative review was conducted to understand the aetiology of traumatic TSI, with a focus on sporting causes in youth populations. A literature search was conducted through various databases (from inception to April 2024) such as PubMed, CINAHL, Medline, ProQuest Central, Science Direct and SPORTDiscus. Seven studies, including 1670 patients were included in the dataset. TSI, particularly fractures, were found to be more common in adolescent age groups. Common sporting causes of spinal trauma included equestrianand team ball/contact sports. This review found few studies failed to correlate the mechanism of injury and the specific spinal level affected, supporting the need for further research.

Keywords: Thoracic Spine Injury; Spine; Epidemiology; Sport; Youth; Paediatric

Background

Injuries to the spine are rare in young children but increase significantly in adolescence. Thoracic spine injuries (TSI) for example are increasing in prevalence among youth and adolescents across the globe resulting in a significant increase in the cost of care [1–3]. According to the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP), spinal injuries were most prevalent in those aged 14 to 16 years with the majority occurring in boys (63%) [4]. The TSI's occurred during recreational and/or sports activities (53%) followed by motor vehicle accidents (26%) and falls from heights (13%). Hospitalization was required in 60% of cases. Fractures were documented in 67%, and 26% had an associated neurologic injury. However, the CHIRPP data may be outdated and despite their increasing prevalence, epidemiological data on thoracic spine injuries is under-presented in the literature, compared to that of cervical and lumbar spine injuries [5]. Of the epidemiological data that is available, few comprehensively examine the thoracic spine. In New Zealand for example, the Accident Compensation Corporation has a vast amount of data relating to injuries. However, even the ACC data fails to examine TSI as its own entity and often combines TSI along with cervical spine or lumbar spine injuries [6].

The thoracic spine is relatively stable and therefore is considered a low injury risk [7]. The nature of traumatic spinal injury may differ with age. In adults, thoracolumbar fractures (T12 to L1) tend to be most common as this junction allows for more movement, increasing injury risk [8]. In older children and adolescents, thoracic spine injuries seem to be most common [8–10]. However, it is important to note that the response to trauma differs in youth and adolescents as their spine matures at a variable rate which implies that the biomechanical property of the developing spine is different from that of an adult spine [12]. Therefore, the mechanism of TSI is crucial to further understand the prognosis of adolescents and youth with TSI. There are three main mechanisms of TSI seen in adolescents such as flexion (with or without compression); distraction; and shear. The most common are hyperflexion injuries resulting in a compression failure of the anterior column, leaving the middle

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column intact. However, a major limitation of several studies done on TSI is that they fail to correlate mechanisms of injury to the specific spinal regions injured [8,9,13].

Sporting injuries are the main reason for youth and adolescents to experience TSI; especially, team ball sports are thought to increase injury risk due to the potential for forced contact with other players [14]. Gupta et al. [9] found thoracic spine fractures to be the most common site of spinal fractures when examining youth sports-related trauma to the spine. Eime et al. [15] found participation in team ball sports tends to be highest from age five to 19 years. They also found general participation to be increasing with time, however, those aged 10 to 14 saw a more considerable increase in participation rates. Systematic review and meta-analysis by Hulteen et al. [16] examined sports and leisure participation rates globally. When examining the adolescent population they found soccer, netball and rugby to be some of the most popular activities in Africa, soccer, basketball and volleyball in the Americas, soccer in the Eastern Mediterranean, soccer and basketball in Europe, and basketball in the Western Pacific. A systematic review by Chan et al. [17], found New Zealand had the third highest number of traumatic spinal cord injuries (TSCI) due to sports in the world. This is thought to be partly attributed to our prominent rugby culture. Studies based in South Africa and Australia have shown a higher rate of TSCI, again, thought to be due to rugby/ball-based play, including scrummage, ruck, mauls and tackles. Gupta et al. [9] found contact sports to be the second most common sport resulting in youth traumatic spinal fractures. Taken together, these findings make it imperative to examine TSI in youth sports including site of TSI and the common mechanisms of TSI.

Research Question and Objectives

The aims of the review were to (1) understand common injuries of thoracic spine in youth playing team ball sports; (2) investigate the aetiology of youth TSI related to sport and recreation; and (3) explore the common mechanisms that result in TSI.

Operational definition: for the purpose of this review, a thoracic spine injury can be described as an injury to the thoracic vertebrae, thoracic spinal cord segment, or other structures that articulate with these.

Focus of this review: Team ball sports will be considered due to the potential for forced contact with other players therefore increasing injury risk. Injuries will be examined in those aged between five to 18 years of age.

Methods

Design: The current study used a narrative review design. Narrative reviews are useful for preliminary synthesis of literature, exploring relationships in the data, identification of gaps and to present trends in the literature [18–20].

Search strategy: A literature search was conducted through various databases (from inception to April 2024) such as PubMed, CINAHL, Medline, ProQuest Central, Science Direct and SPORTDiscus using the strategy outlined in Table 1. The search was limited to articles published in English.

Eligibility criteria: Epidemiological studies that investigated either sporting-related mechanisms of spinal injury or youth spinal trauma populations, or both were prioritized. Studies investigating any TSI were included (fracture, SCI, subluxation, SCIWORA etc.).

Studies were excluded if they did not specify injury relating specifically to the thoracic spine, including discussing only thoracolumbar injury without thoracic data differentiated. Studies examining spinal injury via one mechanism of injury i.e., motor vehicle accident, were not included, to better understand injury aetiology. Studies were excluded if they did not examine youth populations and did not well describe different sporting mechanisms of injury.

Data management and extraction: Articles obtained by the systematic search were exported and saved into reference management software (endnote) and duplicates were removed. Two authors (TN and KSK) formed a consensus decision to extract the following data from each study: Study's aim; Study's characteristics (including number of participants, age, gender, injury diagnosis,

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mechanism of injury, sports played); and Study's findings (including short-term and long-term follow-up).

Data synthesis: consistent with the study's aims, the data were synthesized based on the major concepts: (1) type of injury (2) paediatric injuries (3) injury etiology and mechanism and (4) use of imaging.

Table 1. Search strategy.

Phase 1	Phase 2	Phase 3	Phase 4
1. Traumatic spine injury 2. Spine Injury 3. Spinal injury 4. Spinal fracture 5. Vertebrae Injury 6. Vertebral injury 7. Spinal cord 8. OR/ 1-7 9. Tibial 10. Shoulder 11. Head 12. Chest 13. Thorax 14. Cardiac 15. Non-traumatic 16. Atraumatic 17. Non traumatic 18. NOT/ 9-17	19. Epidemiology 20. Incidence 21. Prevalence 22. Occurrence 23. AND/19 - 22	24. Pediatric 25. Paediatric 26. Child 27. Children 28. Adolescent 29. Young person 30. AND/24-29	31. Thoracic spine 32. Thoracic 33. Thoracic trauma 34. AND/31-33

Results

The database search retrieved a total of 1045 studies. Twelve duplicates were detected and removed by Covidence resulting in 690 references for title and abstract screen, then 79 for full-text review, and finally, 15 studies were included in the final selection (refer Figure 1). Seven publications were included in the final review [21–27]. The characteristics of these studies can be seen in Table 2. The reasons for exclusion are summarised in Figure 1.

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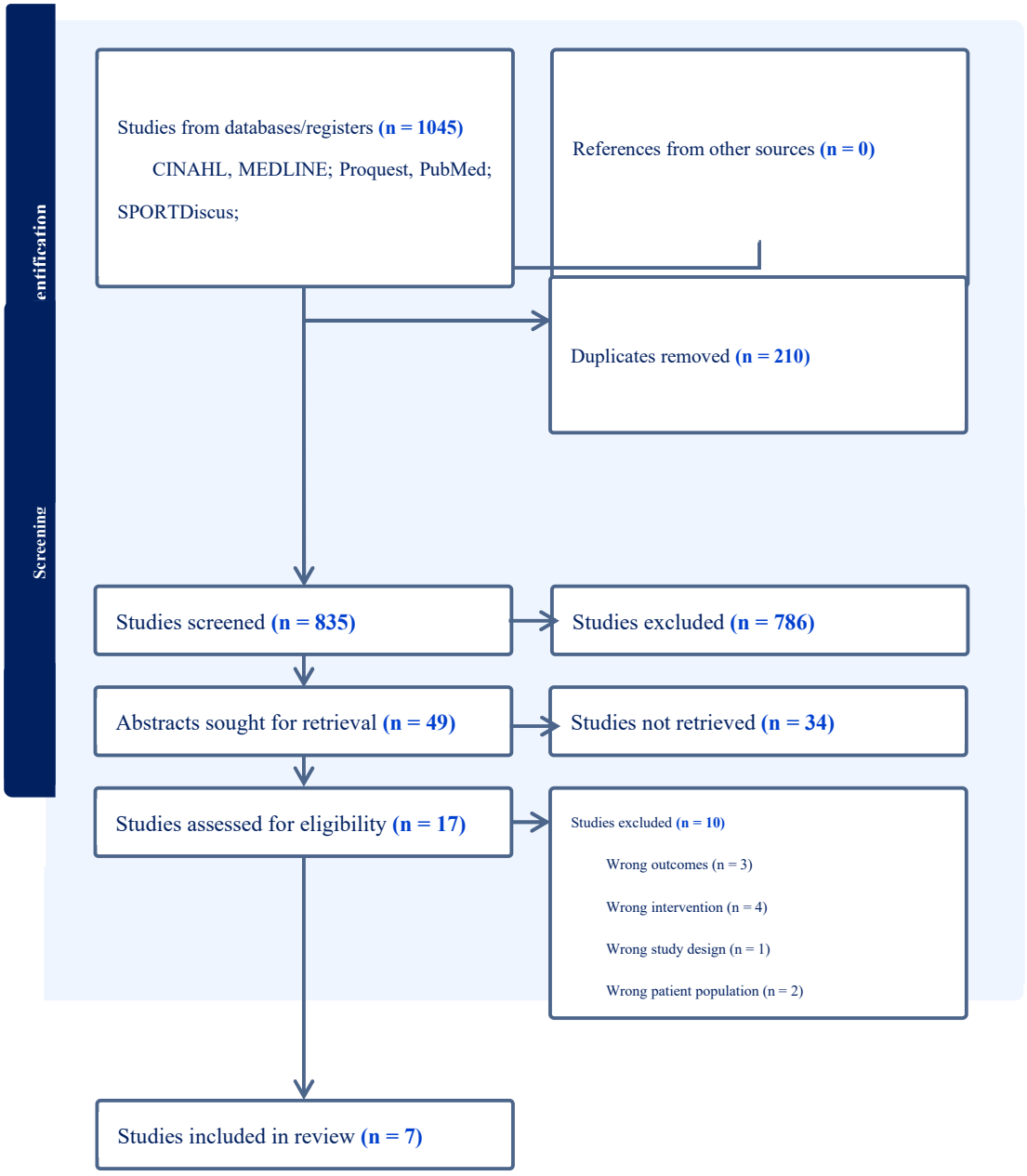

Figure 1. PRIMSA Flow Diagram of Included Studies.

Across the seven studies, 1670 patients were included. Six studies were retrospective [21,22,24–27] and one was prospective [23]. Four studies exclusively examined paediatric populations, [21,22,25,26] while three examined all ages [23,24,27]. Two studies solely examined sporting causes of traumatic spine injury [23,27] while the remaining five discussed general injury aetiologies [21,22,24–26]. Three of these five were able to break down sporting causes into specific sporting activities [24–26]. Injury aetiologies can be seen in Table 3.

Table 2. Characteristics of included studies.

Author, year	Design	Study characteristics	Main Findings	Study Limitations
Al-Habib et al., 2014	Retrospective	Traumatic spinal injuries in patients under 19 years of age at Medical centre between May 2001 and May 2009.	MVC was the most common injury aetiology at 60.8%, followed by pedestrian injuries at 90.8%, then fall	Unable to define "Traumatic Spine Injury" Single centre study

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		120 patients were included, making up 141 spinal fractures. The mean age was 13.5 years.	related injuries at 15%. MVC injuries were most commonly seen in 12-18 year olds. Falls and pedestrian related injuries were seen in children under 12. Overall, cervical injuries were most common 55.8%. Thoracic injury was most common in 12-18 years. 19.2% suffered SCI. The average age was 13.7 years. Thoracic SCI was most common.	Patient population did not include minor injuries
Babu et al., 2017	Retrospective	Children with thoracolumbar trauma (fractures, dislocations, discoligamentous lesions and/or spinal cord injuries) occurring between 2002 and 2014, aged under 18 years. 90 children with thoracolumbar spine injuries were included. The mean age was 15.9 years.	71.1% were inured falling from a height, 20% from MVA, 6.7% following fall of a heavy object , 1.1% from trivial fall, and 1.1% diving from diving. 34.4% of injuries occurred in the thoracic spine. These were most commonly fractures, followed by subluxation and SCIWORA. The lumbar spine was the most common level injured making up 53.3% on injuries. 81% of TL injuries occurred in the 15-18 age group. 23.1% had SCI. These were mostly graded Frankel A.	Unable to break down age, gender and mechanism into spinal segment injured. Single centre study Retrospective
Boran et al., 2011	Prospective	Examined all patients admitted under The National Spinal Injuries Centres between 1993 and 2003.	Sports related spinal injuries made up 11% of all admitted spinal injuries. Equestrian injuries made up 41.8% of all	Did not directly assess paediatric population. Unable to break down injuries into specific injuries

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		196 spinal injuries were admitted. This included 145 males and 51 females, with an average age of 30.2 years, extending from 14 to 72 years.	injuries, followed by rugby 16.3%, diving 15.3%. 60% are injuries occurred in the cervical spine, 21% in the thoracic and 19% in the lumbar spine. In 40% of patients more than one vertebral level was injured, and in 9.25% more than one region was injured. Neurological injury was seen in 36% of patients, 65% of these were incomplete and 25 complete	
Mitchell et al., 2020	Retrospective	Retrospective data from Auckland Spinal Rehabilitation Unit and Burwood Spinal Unit over 10 years was examined. 929 patients, over the age of 16 were included. The mean age was between 43 to 48.	The highest incidence of TSCI was in Māori. Transport accounted for 32% of injuries, falls 31% and sports 21%. MVA and sports causes were more common in younger age groups. Team ball sports was the most common sporting cause making up 20% of sporting injuries. In the 16-30 year old age group, team ball sports caused 31% of sporting spinal injuries. Cervical TSCI made up 54% of injuries, thoracic 28% and lumbosacral 18%. Thoracic injury was most common in 16 – 45 year olds. Cervical TSCI was more common in older age groups.	Age group 16 and above. Failed to break down common aetiologies for each spinal region. Retrospective
Payr et al., 2021	Retrospective epidemiological	Evaluation of patients aged 0 to 18 years with spinal fractures,	52.8% of fractures occurred in the 16 to 18 year aged group.	Single centre study Retrospective

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		presenting to a level 1 trauma centre between January 2002 to December 2021 144 patients with a mean age of 14.5 years, and 269 fractures were included. The population consisted of 40.3% female and 59.7% male	Falls from a height caused 45.8% or fractures, followed by sport incidents causing 29.9%, then road accidents at 20.8%. Skiing was the most common sporting cause of injury. Sporting injuries increased between 2002 and 2019. The thoracic spine was the most common fracture site, followed by lumbar then cervical. L1 was the most commonly injured vertebra. 5.6% of patient present with neurological deficits, this was most common in adolescents and sporting injuries	Limited to fractures only Failed to break down common aetiologies for each spinal region fractured.
Reddy et al., 2003	Retrospective	Patients under 18 years of age with a vertebral fracture and/or a neurological injury that were referred to Spectrum Health trauma service between 1996 and 2001. There were 134 patients; 84 patients with vertebral fractures and 50 neurological injury without radiographic abnormality included. The average age was 16 years. There were 56 males and 28 females.	Thoracic fractures made up the majority of fractures 28.7%, followed by lumbar 23.2% and mid-cervical 18.9%. The thoracolumbar junction (T11-L1) made up 18.9%, the cervicothoracic junction (C7-T1) 7.9% and C0-C2 6.7%. Thoracic fractures were most common in the 9-14 year old age group, closely followed by 15 -17 year olds. MVA incidents accounted for 83 injuries. Thoracic fractures were most common	Failed to break down common aetiologies for each spinal region fractured, only MVA and non-MVA. Neurological injury levels were not outlined. Single centre study Retrospective

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			in the MVA and non-MVA group. Neurological injury without fracture was most common in the 0-8 age group.	
Ye et al., 2009	Retrospective	Patients with sports and recreation related SCI presenting to six institutions between 1993 and 2006 were examined. 57 patients were included in the population. The mean age was 24.5 years. 77.2% were males and 22.8% were females.	64.7% occurred from water sports, 35.1% other incidents. 63.2% of injuries occurred in 12-29 age group. Cervical cord injuries made up 89.5% of injuries, and thoracic 10.5%. Diving caused 59.6% of water based SCI. Dancing was the most common cause of thoracic SCI, ranging from T9 to T12. ASIA A injuries made up 56.1% of injuries.	Small population size Retrospective

Filters used: Language: English; Peer Reviewed. MVA – motor vehicle accident, MVC – motor vehicle collision, RTA – road traffic accident, SCI – spinal cord injury, SCIWORA – spinal cord injury without radiographic abnormality, TL – thoracolumbar, TSCI – traumatic spinal cord injury.

Table 3. Injury aetiology by percentage of spinal injuries per study.

	MVA	Road incidents/transport (MVA and pedestrian)	Pedestrian	Falls	Sports	Other or unspecified
Al-Habib et al., 2014	60.8%		20.80%	15%		3.4%
Babu et al., 2017	20%			73.30%		6.6%
Boran et al., 2011					100%	
Mitchell et al., 2020		32%		31%	21%	
Payr et al., 2021		20.8%		45.8%	29.9%	3.5%
Reddy et al., 2003	61.9%		4.5%	11.2%	11.9%	11.9%
Ye et al., 2009					100%	

Injury Types

A detailed breakdown of specific spinal injuries can be seen in Figure 2. Four studies discussed spinal fractures [21,22,25,26]. Three of these studies were able to outline the spinal region injured [23,25,26]. Across these studies, thoracic fractures were the most common fracture with 213 total. This

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was followed by 180 lumbar fractures, 72 cervical fractures, 33 thoracolumbar fractures and 13 cervicothoracic fractures. Thoracic fractures were found to be most common in adolescent age groups.

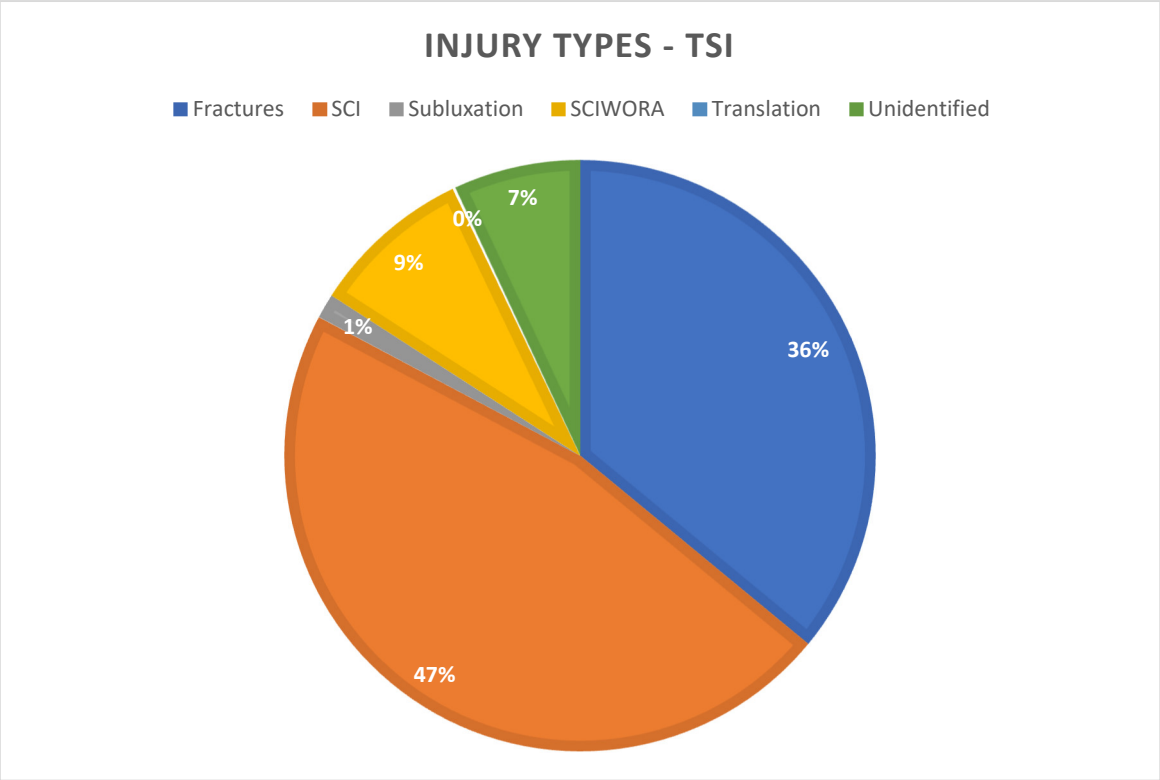

Figure 2. Common Thoracic Spine Injuries.

SCI was discussed in three studies [21,24,27]. Only one of these was in paediatric populations [21]. Cervical SCI were most common with 561.66 injuries, followed by 277.12 thoracic SCI, and 177.22 lumbar SCI. Thoracic SCI were more common in younger age groups. Of the SCIs that were classified, ASIA A or Frankel A were the most common classification.

Subluxations were discussed in one study [22]. A total of 12 subluxations were identified, four in the thoracic spine, four in the TL junction and four in the lumbar. Translation injuries were discussed in one study [22]. One case of translation was found in the TL junction. SCIWORA were discussed in two studies [22,26]. A total of 52 SCIWORA were discussed. Two SCIWORA occurred in the thoracic spine, the remaining 50 were not classified into spinal regions.

A total of 196 spinal injuries were unspecified but were divided into injuries by spinal region [22]. Cervical traumatic spine injury was most common with 118 injuries, followed by 41 thoracic and 37 lumbar. These were not in a paediatric population and ranged from 14 to 72 years.

Paediatric Injuries

Of the four paediatric-based studies [21,22,25,26], the thoracic spine was the most commonly injured, including 213 fractures, 11 SCI, four subluxations and two SCIWORA. The cervical spine had 72 fractures and nine SCI. The lumbar spine had 180 fractures, 10 SCI and four subluxations. A further 191 injuries were not classified into regions.

Injury Aetiology and Mechanism

Four studies did not differentiate spinal regions affected based on the injury aetiology [21,22,24,25]. In one of the remaining three studies [23,26,27], MVA versus non-MVA were the only mechanisms where the spinal injury region was directly linked to a specific spinal region [26]. Two studies reported solely sporting-related spinal injuries [23,27]. In three other studies, sporting causes were discussed but not the main focus [24–26]. Sporting causes of spinal injury can be seen in Table

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4. Equestrian was the most common cause of injury, closely followed by team ball/contact sports. Water sports, particularly diving, and wheeled non-motor sports, such as cycling were also prominent.

Table 4. Sporting causes of traumatic spine injury.

	Team ball/contact	Wheeled non-motor	Water sports	Wheeled motor	Ice/Snow	Equestrian	Gymnastics/acrobatics/dancing	Other
Boran et al., 2011	24.4% (48)	4.2% (8)	15.3% (30)	3.5% (6)	1.2% (2)	41.8% (82)	0.6% (1)	12% (20)
Mitchell et al., 2020	20% (36)	18% (32)	18% (32)	11% (19)	9% (15)%	7% (13)		18% (30)
Payr et al., 2021					21% (9)			
Reddy et al., 2003	40% (4)		60% (6)					
Ye et al., 2009	7% (4)	64.9% (37)			1.75% (1)%		17.8% (10)	8.8% (5)

*Reported as a percentage of total sport-related injuries.

Imaging

Three studies discussed imaging [22,25,26]. In one study, CT was used for all patients [26]. In another study, CT scans were utilised if a fracture was unclear on plain radiology, or for those undergoing surgical intervention, MRI was used when neurological deficits were seen, or in those undergoing surgical intervention [22]. In the other study, plain radiography, CT and MRI were all discussed in diagnostics; however, it was unclear which participants had received which imaging [25]. The remaining four studies did not outline imaging used in the inclusion criteria; however, this was likely a part of a referral process to a centre, or a requirement to be included in a spinal trauma database [21,23,24,26].

Discussion

Summary

This review shows that among traumatic spine injuries, the thoracic spine is the prominent region injured. Thoracic injuries, particularly fractures, tend to be more common in adolescents. This review found few studies failed to correlate the mechanism of injury and the specific spinal level affected, therefore we cannot be sure if certain mechanisms cause injuries in certain regions. This is a common theme thus far, therefore reinforcing the need for further research into thoracic spine injuries.

Sporting-based spinal injury literature was collected between 1993 and 2006 [23,27]. Therefore, this dataset may not well represent current sports trends. Injuries may have since reduced or increased. Rugby Union, for example, has seen ongoing safety modifications to the code. New Zealand Rugby introduced the 2023 Community Rugby Game Innervations; these include the defensive halfback being offside at scrum. This aims to reduce injury risk to a generally small halfback by preventing tackle by a generally larger loose forward. The first tackle must be below the sternum. This aims to minimize impact and therefore injury to the thorax. The maximum scrum push should be 1.5 metres in non-premier adult and adolescent grades, and 0.5 metres in under 13 age groups. This aims to prevent high-energy trample injuries. Rates of injury may have also increased given rugby participation increasing, with women's rugby on the rise. A report by World Rugby found a

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38% increase in registered female rugby participants globally [28]. Again, this supports the need for new epidemiological data.

Through time, we can see there has been an increase in sport-related spinal trauma.

Payr et al. [25] found spinal fractures from sporting incidents doubled between 2002-2007 and 2014-2019. This was also found in Ye et al. [27] who saw a general increase in sport-related SCI. Non-water-based sports saw the most dramatic increase in SCI, whereas water sports, particularly diving, decreased. This trend is supported by cross-sectional study by Compagnon et al. [29] who found sports incidents make up 34% of spinal injuries. In this study, falls accounted for 47% of injuries, however, it was noted that differentiating falls and sport-related falls was difficult. This is likely most relevant when discussing equestrian-based injuries, as in Boran et al. [23] and Mitchell et al. [24] where fall/thrown from the horse was a common equestrian mechanism of injury.

An et al. [12] report there may be a higher risk of SCIWOA in paediatric patients due to the increased flexibility of facet joints and ligaments, but not the spinal cord itself. Although 50 of the 52 SCIWORA in this review were not classified into a region, the remaining two were thoracic SCIWORA. A systematic review by Carroll et al. [30] found sport-related injury to be the most prevalent cause of SCIWORA. The most common level injured was cervical, then thoracic. The mean age in this study was 10.03 years, however, the study did not break down patient characteristics into spinal regions injured. It would be interesting to understand if thoracic SCIWORA are more common in older children/adolescents. This encourages the need for comprehensive profiling of spinal injuries.

Injury aetiologies were likely influenced based on the location of the studies. For example, skiing was the most common sporting activity for spinal injuries in Vienna, which hosts over 100 ski slopes [25]. Versus, Riyad where traffic-related incidents predominated [21]. This is likely due to the increasing population and traffic, the lack of pavements in larger cities, and speed limits of up to 120km/hour [31]. The range of regional injury mechanisms makes it difficult to compare these epidemiological studies. Sport-related spinal injuries based in Ireland are likely the most comparable dataset to Aotearoa in a population and sporting activity sense.

It is thought that plain radiography (x-ray) may not be accurate in identifying minor trauma thoracic spine fractures [32]. Lee et al. [33] found the diagnostic accuracy of X-rays in upper thoracic region vertebral fractures to be lower than in other regions. This may mean thoracic fractures may be underreported in those studies that only used plain radiographs as a part of their inclusion criteria. Children are thought to be more vulnerable to imaging-related radiation than adults, however, MRI does not pose this risk [34]. MRI is considered the most appropriate imaging modality for clearing the paediatric spine of injury [35]. Secondary to this, MRI may be the only mechanism suitable for detecting SCIWORA [35]. However, this may not be achievable given the time and cost MRI entails.

Limitations

Six of the seven articles were based on retrospective studies, therefore limiting the ability to provide causality. Most studies had small populations and were single-centre studies, therefore limiting external validity. This data may be difficult to compare given the differences in classifying spinal regions. Some studies only reported cervical, thoracic and lumbar injuries, while others also reported junctions as their own entity. There were also differences in what vertebrae were defined as a junction. Reddy et al. [26] describe the TL junction to be T10-L1, whereas Babu et al. [22] describe the junction as T12-L1. We did not do critical appraisal and/or risk of bias analysis of any of the included studies which is another limitation. However, undertaking such an analysis is generally considered to be beyond the scope of a narrative review. We included articles published only in English (language bias) as we neither had the capacity nor the capability to translate (and transliterate) studies published in other languages.

Conclusion

TSI, particularly fractures, tend to be more common in older children and adolescent age groups. Common sporting causes include equestrian and team ball/contact sports. Given the high

participation rates of youth in team ball sports, particularly rugby, this population may be more at risk of spinal injury. Generally, studies included in the review failed to correlate the mechanisms of injury to the spinal region injured. Further research should be undertaken to understand mechanisms relating to TSI, which will provide crucial insights for diagnosis and management.

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