Abstract

**Objectives:** To report the incidence of presentations to emergency departments (EDs) in Victoria for sport- and active recreation-related injuries; to establish which sports have the highest rates of injury per participant; to assess the effects of age and sport type on the rate of serious sport injury (resulting in admission to hospital).

**Design, setting and participants:** Retrospective analysis of 171 541 ED presentations to 38 Victorian hospitals, 2012–13 to 2014–15. Sports- and active recreation-related injuries in people aged 5 years or more were identified from coded data and by text searches.

**Main outcome measures:** Population rates of injuries by sport and ranking of sports by per participant injury rates (for people aged 15 years or more); proportions of presenting patients subsequently admitted to hospital (serious sport injuries) (for people aged 5 years or more).

**Results:** During 2012–13 to 2014–15, there were 171 541 presentations to EDs with sports-related injuries. Sports most commonly associated with presentation by people aged 15 years or more were Australian football, motor sports, and cycling/BMX; the highest per participant injury rates (people aged 15 or more) were for motor sports, rugby, and skateboarding INLINE hockey/roller sports. 11% of ED patients aged 5 years or more were subsequently admitted to hospital; the odds of admission were highest for those with injuries from motor sports, horse riding, or cycling/BMX.

**Conclusions:** Assessing sports injury rates corrected for participation rates and evaluating the relative severity of injuries is important for monitoring safety. Our findings can assist decisions about which sports should be the focus of injury prevention efforts.

**Methods**

**Data sources**

We undertook a retrospective case series analysis based on ED presentations data extracted from the Victorian Emergency Minimum Dataset (VEMD), which records information (including level 1 injury surveillance data) from 38 Victorian public hospitals providing a 24-hour ED service. These hospitals account for about 80% of ED presentations in Victoria. Data collection was in accordance with National Minimum Data Standards for injury surveillance. Cost data were extracted from the Victorian Cost Data Collection (VCDC), which contains data on the average costs (direct and indirect) of treating patients in EDs according to age group, sex and diagnosis code.

Two types of denominator data were employed. Residential population data for the age groups ≥ 5 and ≥ 15 years in Victoria for the period 2012–13 to 2014–15 were available for calculating population injury rates. Participant injury rates during 2013–14 were calculated from sports participation data for the ≥ 15 years age group.

**The known** The number of patients treated in hospital for sport-related injuries has increased in recent years, placing an increasing burden on the health service system.

**The new** In Victoria, the sports associated with the highest numbers of presentations of people aged 15 years or more to emergency departments are Australian football, motor sports, and cycling/BMX, but participant injury rates are highest for motor sports, rugby, and skateboarding and similar activities, while hospital admission rates are highest for horse riding, motor sports, and cycling/BMX.

**The implications** Sports injury prevention initiatives should focus on sports associated with high per participant injury rates or with relatively severe injuries.
1 The twenty sport and recreational activity types associated with the highest numbers of injury-related presentations to emergency departments (EDs) by people aged 15 years or more (initial presentations only), Victoria, 2012–13 to 2014–15*

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<tbody>
<tr>
<td></td>
<td>ED presentations</td>
<td>Annual injury</td>
</tr>
<tr>
<td></td>
<td>(proportion of overall total)</td>
<td>rate, per 100 000</td>
</tr>
<tr>
<td>Australian football</td>
<td>20 784 (17.9%)</td>
<td>146.6</td>
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<tr>
<td>Motor sports</td>
<td>9655 (8.3%)</td>
<td>68.1</td>
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<tr>
<td>Cycling/BMX</td>
<td>8432 (7.3%)</td>
<td>59.5</td>
</tr>
<tr>
<td>Basketball (indoor/outdoor)</td>
<td>7991 (6.9%)</td>
<td>56.4</td>
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<tr>
<td>Soccer (indoor/outdoor)</td>
<td>7227 (6.2%)</td>
<td>51.0</td>
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<tr>
<td>Netball (indoor/outdoor)</td>
<td>5483 (4.7%)</td>
<td>38.7</td>
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<tr>
<td>Horse riding/equestrian activities/polo</td>
<td>4825 (4.2%)</td>
<td>34.0</td>
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<tr>
<td>Skateboarding/inline hockey</td>
<td>4593 (4.0%)</td>
<td>32.4</td>
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<tr>
<td>(indoor/outdoor)/roller sports</td>
<td></td>
<td></td>
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<tr>
<td>Cricket (indoor/outdoor)</td>
<td>3527 (3.0%)</td>
<td>24.9</td>
</tr>
<tr>
<td>Ice/snow sports</td>
<td>1888 (1.6%)</td>
<td>13.3</td>
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<tr>
<td>Dancing/ballet</td>
<td>1665 (1.4%)</td>
<td>11.7</td>
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<tr>
<td>Hockey (indoor/outdoor)</td>
<td>1476 (1.3%)</td>
<td>10.4</td>
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<tr>
<td>Rugby</td>
<td>1405 (1.2%)</td>
<td>9.9</td>
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<tr>
<td>Weightlifting/powerlifting/body building</td>
<td>1074 (0.9%)</td>
<td>7.6</td>
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<tr>
<td>Martial arts</td>
<td>1057 (0.9%)</td>
<td>7.5</td>
</tr>
<tr>
<td>Athletics (track and field)</td>
<td>984 (0.8%)</td>
<td>6.9</td>
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<tr>
<td>Fishing</td>
<td>967 (0.8%)</td>
<td>6.8</td>
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<tr>
<td>Surf sports</td>
<td>925 (0.8%)</td>
<td>6.5</td>
</tr>
<tr>
<td>Water skiing/powerboating</td>
<td>891 (0.8%)</td>
<td>6.3</td>
</tr>
<tr>
<td>Swimming/diving</td>
<td>869 (0.8%)</td>
<td>6.1</td>
</tr>
<tr>
<td>Total for top 20 sport/recreation types</td>
<td>85 718 (74.0%)</td>
<td>604.8</td>
</tr>
<tr>
<td>Other sport/recreation types</td>
<td>30 109 (26.0%)</td>
<td>212.4</td>
</tr>
<tr>
<td>Total</td>
<td>115 827</td>
<td>817.2</td>
</tr>
</tbody>
</table>

* Sources: Victorian Emergency Minimum Dataset (Injuries), Australian Bureau of Statistics (population data),\(^\d\) customised extraction from catalogue data for Victoria by the Bureau (sports participation data [2013–14]). \(^\d\) Players, competitors, or persons aged 15 years or more who participated in a physically active role during the 12 months prior to injury. \(^\d\) Hockey played on roller skates. \(^\#\) Standard error for estimate of participation, 25–50%; to be used with caution. \(^\*\) Standard error for estimate of participation, > 50%; estimate classed as unreliable.

Injury case selection
ED presentations between 1 July 2012 and 30 June 2015 by people aged 5 years or more were included. As data for sports participation were only available for people aged 15 years or more, cases selected for participation-adjusted injury rate calculations were limited to this age group; to allow comparisons, these cases were also selected for calculating matching population injury rates.

An algorithm was developed for selecting cases in which injury resulted from being engaged in sport or active recreation, including “activity when injured” and “place where injury occurred” variables, and the “description of injury event” (patient’s personal account or description of injury event, provided at triage)\(^\d\) (online Appendix, box 2). No distinction was made between organised and non-organised sport, as this information was not consistently available in the VEMD. Data selection was limited to incident cases (excluding return ED visits and pre-arranged admissions). Those requiring subsequent hospital admission (ie, patients admitted directly from an ED to a hospital ward or unit) were identified. Patients coded as deceased on discharge were excluded from analysis of subsequent hospital admissions.

Statistical analysis
Analyses were conducted in Stata 14.0 (StataCorp). \(\chi^2\) tests and binary logistic regressions (univariate and multivariate models) were employed; the binary model outcome was subsequent admission \(v\) no subsequent admission to hospital. The main explanatory variable of interest was sport type. Because participation and the type of sport played varied considerably by sex, the analyses were stratified by this factor and different sports served as reference groups (Australian football for males, netball for females). All reported results are for the sample aged 5 years or more, except Box 1, which is based on a subsample of those aged 15 years or more.
Results

Emergency department presentations

There were 1 036 978 presentations for injuries by people aged 5 years or more to the VEMD-reporting hospitals in Victoria during 2012–13 to 2014–15, of which 171 541 (17%; 57 180 per year) were related to sport or active recreation. The number of sports injury-related ED presentations increased from 54 789 in 2012–13 to 60 734 in 2014–15 (11% increase), or from 1031 to 1102 per 100 000 population (7% increase). Of these patients, 18 666 (11%) were subsequently admitted to hospital.

The twenty sports associated with the highest numbers of ED presentations by people aged 15 years or more accounted for 85 718 presentations, or almost 74% of all sports injury ED presentations in this age group. The sports associated with the highest numbers of presentations were Australian football, motor sports, and cycling/BMX, but the participant injury rates were highest for motor sports, rugby, and skateboarding and other roller sports (Box 1).

Almost two-thirds of ED presentations with injuries associated with the top twenty causes of sport-related injury were by people aged 5–24 years; 30 819 presentations (24%) were by people aged 25–44 and 9820 (8%) by people aged 45 or more. Males accounted for 91 333 injury presentations (72%) associated with these sports, but the proportion differed by sport (Box 2).

An estimated $17.9 million was spent annually on ED presentations for sports-related injuries incurred in the twenty sports with which the greatest numbers of presentations were associated. The sports associated with the highest total ED costs were Australian football, motor sports, and cycling/BMX; the sports with the highest costs per presentation were motor sports, horse riding, and cycling/BMX (Box 3).

Hospital admissions after presentation to an emergency department

The proportion of patients aged 5 years or more admitted to hospital after presenting to an ED was greatest for injuries incurred during horse riding, motor sports, and cycling/BMX. The highest absolute number of hospital admissions were for motor sports (3239), cycling/BMX (2501) and Australian football (2483) (Box 4).
We restricted further analysis of admission to hospital after an ED presentation to the ten sports that most frequently resulted in injury ED presentations for each sex; these cases accounted for 82,728 presentations by males (68% of all sport-related presentations) and 30,730 by females (62%). The final reduced model included age, region and sport as factors, and an age—sport interaction (Box 5).

After adjusting for age and region, the odds of males presenting to an ED being admitted to hospital were greatest for injuries related to motor sports (Australian football: adjusted odds ratio [aOR], 3.99; 95% CI, 3.63–4.38), horse riding or other equestrian activities (aOR, 3.31; 95% CI, 2.34–4.68), and cycling/BMX (aOR, 2.20; 95% CI, 1.94–2.50; for each, \( P < 0.001 \)). The odds for basketball, soccer, and cricket were lower than for Australian football (all \( P < 0.001 \)) (Box 5, online Appendix, figure 1).

After adjusting for age and region, the odds of females presenting to an ED being admitted to hospital were greatest for injuries related to horse riding/equestrian activities (netball: aOR, 18.3; 95% CI, 13.5–24.8), motor sports (aOR, 12.5; 95% CI, 8.74–18.0), and cycling/BMX (aOR, 8.65; 95% CI, 5.71–13.1; for each, \( P < 0.001 \)) (Box 5, online Appendix, figure 2).

Higher age was associated with a significantly increased likelihood of hospital admission for both sexes (Box 5).

### Discussion

The sports associated with the highest numbers of injury-related presentations to EDs by people aged 5
years or more were Australian football, motor sports, cycling/ BMX, basketball, soccer, and netball. An earlier study\textsuperscript{14} found that football, basketball, netball, hockey, and cricket were associated with the highest numbers of presentations to EDs; we found that injuries from motor sports and horse riding were more frequent than for cricket or hockey.

The highest injury rates per participant among those aged 15 years or more were for motor sports, rugby, and weightlifting. Australian football, and horse riding. Swimming, cycling, and cricket had high participation rates, but injury rates were relatively low. A 2003 study of sports participation and injuries in the Latrobe Valley, Victoria, found that Australian football, cycling, and basketball were associated with the highest per participant injury rates in people aged 5 years or more.\textsuperscript{4} The difference between these findings and ours result from the large standard errors for participation estimates for motor sports, rugby, and weightlifting in our study, and the inclusion of children under 15 in the Latrobe study. Motor sports have been reported to have the highest per participant injury rates in Australia,\textsuperscript{2} consistent with our findings.

The sports and recreation activities with the highest odds of hospital admission following presentation to an ED were horse riding, motor sports, and cycling/BMX. Few sports injuries studies have focused on the activities most frequently associated with severe injury; an American study found that all-terrain vehicle riding, motocross, and horse riding had high relative risks of hospital admission, while the relative risks for basketball and soccer were low,\textsuperscript{15} consistent with our findings.

Higher age was significantly associated with subsequent hospital admission; only 8% of ED presentations in our study were by people aged 45 or more, but they were significantly more likely than younger patients to be admitted to hospital. This is consistent with earlier research which found that the odds of hospital admission increased with age.\textsuperscript{15}

Total ED treatment costs were highest for Australian football-related injuries, but the cost per incident was relatively moderate; both total costs and cost per incident were high for motor sport-related injuries, while total costs for horse riding injuries were lower, but the cost per incident was high.

**Strengths and limitations**

One strength of our study was that coverage of sport injury-related presentations to EDs was near complete, although the VEMD does not include cases treated at EDs in private hospitals. Our study is one of few to analyse sports injuries in Victoria stratified by sex, adding another layer of information to previous work.\textsuperscript{6,16} Other strengths include our methods for identifying cases, and our inclusion of exposure data.

The quality of case selection relied on accurate coding and good narrative recording by ED staff. The quality of VEMD data varies.
between hospitals; some do not provide accurate coding and informative text narratives, or text narratives that match coded fields. Coded fields (eg, “activity when injured”) were used for identifying cases, but in the VEMD not all sports injury cases are coded as sport-related. We diminished this problem by screening text narrative to identify sports injury cases not coded as such. The narratives also have quality problems, relying on the accuracy and completeness of reporting, but this is likely to be consistent across all sports injury presentations and unlikely to affect relative injury rates.

Injury rates based on sports participation rates rather than on general population numbers is preferable, but participation data for children aged 5–15 years was not available in the survey data supplied. The reliability of participation data was also limited by survey constraints, with relative standard errors exceeding 25% for some sports; the estimates for motor sports and rugby are considered unreliable. Further, the survey participation estimates were sometimes lower than cited by other sources. For example, participation in Australian football in 2013–14 was estimated to be 121,000, but the most recent Australian Football League survey (2017) reported 462,000 participants; the 2015–16 cricket census reported 328,000 Victorians playing cricket, compared with 92,000 in the sports participation survey. These differences can largely be attributed to differing data collection methods, and verifying per participant injury rates will require further research.

It was not always possible to distinguish between sport and similar non-leisure activities (eg, cycling as a mode of transport). The incidence of Australian football-related injuries may have been overestimated, as all unspecified football injuries were coded to Australian football because of its popularity in Victoria. Finally, a large proportion of people with sports injuries present to physiotherapists and general practitioners rather than EDs, and injuries not requiring professional medical attention receive on site treatment only. Our study consequently did not reflect the overall incidence of sports injuries in Victoria.

Conclusions
Taking participation into account gives valuable insights into the relative safety of different sports. For example, many injuries are incurred during Australian football, but the injury rate is lower than for motor sports when adjusted for participation. Participation-adjusted sports injury rates and evaluating the risk of subsequent hospital admission, corrected for demographic factors, is useful for sports officials and organisations, health promotion agencies, and others actively monitoring safety in sport. Our findings can help set targets for reducing injury rates and deciding which sports should be the focus of injury prevention efforts.

Age, sex, and type of activity influence the incidence and severity of sports-related injuries treated at EDs and the proportion of patients subsequently admitted to hospital. Efforts to reduce the likelihood of serious injury should concentrate on lower participation sports with higher rates of hospitalisation, such as motor sports and horse riding, and on sports with high per participant injury rates, such as motor sports, rugby, and skateboarding. We recommend further investigation of the settings in which motor sports, horse riding, and other activities are undertaken for reliably evaluating current safety measures.

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