Title:

Characteristics and outcomes of severe sports-related injury in children and adults: a nationwide cohort study in Japan

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Abstract

Purpose: Understanding epidemiological patterns in patients with severe sports-related injuries between children and adults is important for injury prevention. We ought to describe the characteristics and outcomes of patients with severe sports-related injuries and compare the characteristics between children and adults.

Methods: We conducted a retrospective analysis of the Japan Trauma Data Bank (JTDB). We included patients with sports-related injury and an ISS of at least 16, who were admitted between 2004 and 2018. We compared characteristics between children (<18 years) and adults (≥18 years). We performed a multivariable logistic regression analysis to compare in-hospital mortality.

Results: We identified 1,369 eligible patients (children, n=326; adults, n=1,043). The most common season was April–June and July–September in children (28.5% and 27.9%) and January–March in adults (42.1%). Injuries to the head/neck (58.9% vs. 40.8%, p<0.001) and abdomen (16.0% vs. 8.3%, p<0.001) were significantly more frequent in children than adults, while injuries to the thorax (8.0% vs. 27.2%, p<0.001), pelvis/lower-extremity (0.6% vs. 6.0%, p<0.001), and spine (23.9% vs. 35.3%, p<0.001) were less frequent in children. We did not observe a statistically significant difference in in-hospital mortality between children and adults.

Conclusions: We conducted a comprehensive analysis of severe sports-related injuries using a nationwide trauma database and demonstrated different patterns of severe sports-related injuries in children and adults.

Key Words: Sports-related injury; severe trauma; mortality; Japan Trauma Data Bank

Declarations:

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Authors' contributions: S.N. conceived the study. S.N., Y.K. and K.T. participated in the data curation. S.N., Y.K., and T.Kitamura structured the methods and the statistical analysis. S.N. prepared the manuscript. S.N., Y.K., T.Kitamura, K.T., T.H., J.T., K.I., M.O., T.Kiguchi, Y.U., K.K., and J.O. performed the data interpretation. All authors critically reviewed and approved the final version of the manuscript.

Ethics approval: The protocol was approved by the Ethics Committee of Osaka University as the corresponding institution. The requirement for informed consent of patients was waived.

Consent to participate: Since it is an analysis of anonymous data, according to the ethics committee dispositions, no informed consent was needed.

Consent for publication: Since it is an analysis of anonymous data, according to the ethics committee dispositions, no informed consent was needed.

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93

Introduction

Worldwide, trauma is the leading cause of death of individuals under 45 years of age [1]. Although the severity of most sports-related injuries is minor to moderate, severe trauma can occur and cause significant morbidity and mortality [2]. Pediatric major trauma related to sports is reported to be relatively infrequent but increasing as participation in sports for children and youths becomes popular [3–5]. A report from eastern Canada showed that severe traumatic brain injury occurred 52 % of major trauma related to sports and recreational activities in children [3]. A report of pediatric sports-related major trauma from southern Australia showed the most commonly injured body region was the thorax, followed by the head and spine [6]. A recent single-center study of severe pediatric trauma from France reported that the average injury severity score (ISS) was 16 and the major lesions were head (51%) and intraabdominal (30%) injuries in severe injuries following winter sporting accidents [7].

Features of sports-related injury in children may differ from those in adults due to differences in physical activity, muscular development, school environment, and so forth [8–10]. Understanding different patterns in characteristics and outcomes of patients with severe sports-related injuries between children and adults is important for injury prevention. However, there is still a paucity of information on the characteristics of severe sports-related injury and its difference between children and adults. The aim of this study was to describe the characteristics and outcomes of patients with severe sports-related injuries and compare the patterns in the characteristics between children and adults using a Japanese nationwide database.

Methods

Study design and setting

We conducted a retrospective analysis of a nationwide voluntary hospital-based trauma registry, the Japan Trauma Data Bank (JTDB). The institutional ethics committee of Osaka University Graduate School of Medicine approved this study. The requirement for informed consent was waived because of the use of anonymous data (approval no. 16260-3).

The emergency medical system personnel at the scene select hospitals for patient transport including tertiary-care centers according to life-threatening conditions and mechanisms of injury. As there are limited children's hospitals with pediatric trauma specialists in Japan, severe pediatric trauma patients are often brought to tertiary-care centers for adults [11].

Japan Trauma Data Bank

The JTDB was established in 2003 by the Japanese Association for the Surgery and Trauma (Trauma Surgery Committee) and the Japanese Association for Acute Medicine (Committee for Clinical Care Evaluation) [12]. As of 2018, 280 major trauma care facilities throughout Japan had participated in this registry [13]. Data were collected and submitted using a web-based system by medical staff in participating institutions, who completed a training course in Abbreviated Injury Scale (AIS) coding. The JTDB includes the following information about trauma patients: age, sex, mechanism of injury, AIS codes (version 1998), Injury Severity Score (ISS), type of hospital (e.g. tertiary-care center or not), vital signs on hospital arrival, date and time of hospital arrival, procedures (e.g., interventional radiology), surgical operations and computed tomography scans, complications, and mortality at discharge. The ISS is calculated as the sum of the squares of the highest AIS scores in the three most severely injured body regions [14]. Sports-related injury was one of the unique codes for mechanism of injury in the JTDB and was defined as any injury during sporting activity.

144

145 **Participants**

146 Patients with sports-related injuries who were registered in the JTDB with an ISS of
147 at least 16 and who were admitted between 2004 and 2018 were included in this study.
148 Patients whose records were missing information on age, sex or in-hospital mortality, and
149 data that were double-counted due to inter-hospital transport were excluded from the
150 analysis. We divided eligible patients into two groups: children (<18 years) and adults (≥18
151 years).

152

153 **Variables**

154 We extracted the following patient characteristics from the JTDB database: age, sex,
155 blunt or penetrating injury, date and time series from the Emergency Medical System call to
156 admission, AIS codes, ISS, vital signs on hospital arrival, and mortality at discharge. We also
157 extracted whether the patient was managed in a tertiary-care center or not. To evaluate
158 seasonal trends, we divided 12 months into four seasons of three months: January–March,
159 April–June, July–September, and October–December as previously described in previous
160 studies in sports and physical activities [15,16]. We divided the time of day of the Emergency
161 Medical System call into 8-hour time periods (i.e., 00:00–07:59, 08:00–15:59, and 16:00–
162 23:59). To assess the injury sites, we categorized AIS-coded injuries into the following body
163 regions: head/neck, thorax, abdomen, pelvis/lower-extremity, and spine. We also evaluated
164 the maximum AIS severity in these body regions. We defined shock as a systolic blood
165 pressure of <80 mmHg on hospital arrival [17]. We defined shock in children as a systolic
166 blood pressure of <80 mmHg on hospital arrival as previously described in a previous study
167 of trauma in children [18]. We defined out-of-hospital cardiac arrest as a systolic blood
168 pressure of 0 mmHg or a heart rate of 0 bpm on hospital arrival.

To describe the distribution across the stages of age, we categorized age into three groups for children and two groups for adults: childhood (≤11 years), young teens (12–14 years), and teenagers (15–17 years); young adults (18-64 years), and elderly (≥65 years) [19].

Statistical analyses

Continuous variables are presented as the median and interquartile range (IQR) and categorical variables as the number and percentage. Patient characteristics of the two groups were compared using the Mann-Whitney U test for continuous variables and the chi-squared test or Fisher's exact test for categorical variables. To compare in-hospital mortality, we categorized age into three groups, children (≤18 years), young adults (18-64 years), and elderly (≥65 years) and used a multivariate logistic regression analysis and calculated odds ratios (ORs) and 95% confidence intervals (CIs).

Two-tailed P values of <0.05 were considered to indicate statistical significance. All statistical analyses were conducted using the R software program (version 3.6.2; R Foundation for Statistical Computing, Vienna, Austria).

Results

Among 356,535 trauma patients recorded in the JTDB during the study period, 6,669 were categorized as sports-related injury cases and 139,307 were severe injury cases. In total, 1,369 patients with severe sports-related trauma were eligible for inclusion in the analysis (Figure 1). The patient characteristics are summarized in Table 1. The median age of the overall patient population was 30 years and 87.6% of the patients were male. The youngest age in our cohort was 4 years of age, and the oldest was 92 years of age. Most injury was blunt trauma. The most common season of injury was the period of January–March in the total cohort. The most common season in children was April–June closely followed by July–

194 September, while the most common season in adults was January–March; the difference in
195 the distribution of seasons between children and adults was statistically significant. The most
196 common time of day was 08:00–15:59 in children and adults, and difference in the
197 distribution of time of day between children and adults was statistically significant. Sports-
198 related injury in children most frequently occurred at 16:00–23:59. The most common injury
199 site was head/neck in the total cohort. The most common injury site in both children and
200 adults was the head/neck, followed by the spine. Injuries to the head/neck and abdomen
201 occurred significantly more frequently in in children than in adults, while injuries to the
202 thorax, pelvis/lower-extremity, and spine occurred significantly less frequently in children
203 than in adults. Most patients were admitted to the tertiary-care centers in both groups. The
204 median maximum AIS severity was four in the total cohort, and there was no statistical
205 difference between the groups. The median ISS was 17, while the median ISS in children and
206 adults was 16 and 17, respectively. Shock on arrival at the hospital was present in 3.2% of the
207 total cohort and out-of-hospital cardiac arrest occurred in 1.2% of the total cohort. There was
208 no significant difference in shock on arrival or out-of-hospital cardiac arrest between the
209 groups. The overall in-hospital mortality rate was 4.5% and the rates in children and adults
210 did not differ to a statistically significant extent.
211 The associations between patient characteristics and in-hospital mortality are
212 summarized in Table 2. The in-hospital mortality rates of children and adults did not differ to
213 a statistically significant extent. Injury to the head/neck and thorax was associated with
214 significantly worse in-hospital mortality and injury to the spine was associated with
215 significantly better in-hospital mortality.
216 The patient characteristics by age group in both children and adults are described in
217 Table 3 and Figure 2. The most common season in all age groups of adults was January–
218 March. The most common injury through all age groups of children was injury to the

219 head/neck and the second most common injury was injury to the abdomen in childhood (≤11
220 years), injuries to the abdomen and spine in young teens (12-14 years), and injury to the spine
221 in teenagers (15-17 years). The most common injury in young adults (18-64 years) was injury
222 to the head/neck, followed by injury to the spine, and that in elderly (65-74 years) was injury
223 to the spine, followed by injury to the head/neck.
224
225 **Discussion**
226 We reported the characteristics and outcomes of severe sports-related trauma and
227 factors associated with patient outcomes using a Japanese nationwide database. The common
228 seasons for severe sports-related trauma in children was April–June and July–September,
229 while the common season in adults was January–March. We did not observe a statistically
230 significant difference in in-hospital mortality between children and adults. We also described
231 the age-stratified evaluation in severe sports-related injury among children and adults. Our
232 findings should facilitate further investigations to identify the associated factors with
233 morbidity and mortality.
234 Injury to the head/neck and thorax was significantly associated with worse in-hospital
235 mortality, which is consistent with previous studies [20–22]. We observed a paradoxical
236 finding in the association between spinal injury and in-hospital mortality as patients with
237 spinal injury were significantly more likely to survive than those without spinal injury. This
238 may be explained by the under-diagnosis of spinal injury in patients with altered mental state.
239 A previous study reported that the diagnosis of spinal injury was often missed due to
240 concomitant severe head trauma and the low sensitivity of X-ray and CT [23].
241 Previous studies reported that severe trauma is relatively common in winter sports,
242 including skiing and snowboarding [24–26]. As winter sports are popular in Japan, it is
243 reasonable that severe sports-related trauma in adults mostly occurred in January–March.

Sports-related injury in children commonly occurred in April–June and July–September, which can be attributed to the Japanese school system. In addition to regular physical education, which is provided during elementary, junior high school, and high school, junior high school and high school students can also participate in voluntary and extracurricular sports clubs. Inter-school sports activities are popular in Japan, especially the baseball tournaments in spring and summer [27]. Contact sports such as gymnastics, soccer, basketball, and rugby are also popular in junior high and high school in Japan and have higher risk of injury than noncontact sports [28]. These may affect the distribution in season and time of day for severe sports-related trauma in children.

In children, injuries to the head/neck and abdomen were significantly more frequent in comparison to adults, which is consistent with a previous report on injury patterns [29]. Severe head injuries are more common in children due to the greater head-body ratio and thinner cranial bones. Abdominal injuries are more common in children due to their flexible rib cage and less developed abdominal muscles [30]. Previous studies demonstrated that severe sports-related abdominal injuries, such as renal injury, are more likely to occur as in isolated injury in children [31,32]. A previous study that analyzed an international trauma database reported that head, chest, spinal and pelvic injuries were common in major trauma in winter sports [24]. This might be the reason for the larger proportions of chest, abdominal, and spinal injuries in adults in comparison to children, as severe sports-related trauma in adults were occurred in winter in our study. We did not observe a statistically significant difference in in-hospital mortality between children and adults.

We compared the patient characteristics and outcomes in severe sports-related in-jury between children and adults. Although further investigations are needed, our findings suggest injury prevention and safety promotion in sports should be provided with different approaches in children and adults. Our results may help improve trauma prevention and care

in sports. As injuries to the head/neck and spine were common in severe sports-related injury, it may be useful to place greater emphasis on the use of head protective equipment and spine protection devices for sports [33,34]. Our results may suggest that head protective equipment and spine protection devices should be more promoted in both curricular and extracurricular sports including contact sports during spring and summer for children and in winter sports such as skiing and snowboarding for adults.

Limitations

The present study was associated with several limitations. First, although this study was based on a nationwide trauma database in which major critical care centers in Japan participated, the JTDB is not population-based database and the data registration is voluntarily, which may limit the generalization of the results. Our results may not be applicable to areas that have differences in popularity of sports, population age distribution, school education system, or healthcare systems. Second, since JTDB does not include data on the type of sports, we could not analyze details in mechanism of injury. However, we believe that this study is still important to reveal the situation in sports-related injury from a nationwide database in Japan. Further study is needed to address this issue. Third, our study did not include unreported sports-related injury, nor did it capture injuries that occurred through mechanisms outside the coding parameters, as with other trauma database studies [20,21]. We therefore expect that our findings with regard to severe sports-related injury do not estimate its true prevalence. In addition, as we found “paradoxical” protective effect of spine injury to mortality, there may be other factors that skew the results. It is also important to understand that our analysis of mortality was not adjusted for potential confounders such as age groups, injury site, and severity of injury, that may skew the results. Further study is needed to confirm the associated factors with mortality among severe sports-related injury.

Conclusions

We conducted a comprehensive analysis of severe sports-related trauma using a nationwide trauma database. The most common season for severe sports-related trauma was April–June and July–September in children and January–March in adults. In-hospital mortality in children and adults did not differ to a statistically significant extent. Injuries to the head/neck and abdomen occurred more frequently in children than in adults, while injuries to the thorax, pelvis/lower-extremity, and spine occurred less frequently in children than in adults. By elucidating the epidemiology, our study can help improve prevention and care for severe sports-related trauma.

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Figures and Tables legends:

Fig. 1. Patient flow

Fig. 2. Injury sites (AIS 3+) of severe sports-related injury by age group

Table 1. Patient characteristics of severe sports-related injury from 2004 to 2018.

Table 2. Odds ratios of each variable for mortality among patients with severe sports-related injury

Table 3. Patient characteristics of severe sports-related injury by age group in children

Table 4. Patient characteristics of severe sports-related injury by age group in adults

Table 1. Patient characteristics of severe sports-related injury from 2004 to 2018.

	Total		Children		Adults		P value
Characteristics	**n=1,369**		**n=326**		**n=1,043**		
Age, median, Q1-Q3	30	18-46	15	13-16	39	26-50	
Male sex, n (%)	1,199	(87.6)	281	(86.2)	918	(88.0)	0.387
Type of injury, n (%)							0.346
Blunt	1,350	(98.6)	324	(96.3)	1026	(98.4)	
Penetrating	6	(0.4)	0	(0.0)	6	(0.6)	
Missing	13	(0.9)	2	(0.6)	11	(1.1)	
Season, n (%)							<0.001
January-March	517	(37.8)	78	(23.9)	439	(42.1)	
April-June	297	(21.7)	93	(28.5)	204	(19.6)	
July-September	314	(22.9)	91	(27.9)	223	(21.4)	
October-December	241	(17.6)	64	(19.6)	177	(17.0)	
Time of day, n (%)							<0.001
00:00–07:59	31	(2.3)	7	(2.1)	24	(2.3)	
08:00–15:59	950	(69.4)	199	(61.0)	751	(72.0)	
16:00–23:59	346	(25.3)	110	(33.7)	236	(22.6)	
Missing	42	(3.1)	10	(3.1)	32	(3.1)	
Tertiary-care center, n (%)	929	(67.9)	218	(66.9)	711	(68.2)	0.711
Injury site (AIS 3+), n (%)							
Head/neck	618	(45.1)	192	(58.9)	426	(40.8)	<0.001
Thorax	310	(22.6)	26	(8.0)	284	(27.2)	<0.001
Abdomen	139	(10.2)	52	(16.0)	87	(8.3)	<0.001
Pelvis/lower-extremity	65	(4.7)	2	(0.6)	63	(6.0)	<0.001
Spine	446	(32.6)	78	(23.9)	368	(35.3)	<0.001
Maximum AIS severity, median, Q1-Q3	4	4-4	4	4-4	4	4-4	0.620
ISS, median, Q1-Q3	17	16-25	16	16-20	17	16-25	<0.001
Shock on arrival, n (%)	44	(3.2)	9	(2.8)	35	(3.4)	0.714
Out-of-hospital cardiac arrest, n (%)	16	(1.2)	2	(0.6)	14	(1.3)	0.385
In-hospital mortality, n (%)	62	(4.5)	11	(3.4)	51	(4.9)	0.319

P values were calculated using Mann-Whitney U test, chi-squared test, or Fisher's exact test as appropriate.

AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

414 **Table 2.** Adjusted odds ratios of each variable for mortality among patients with severe sports-related injury

Characteristics	Mortality %	Mortality (n/N)	Odds Ratio (95% CI)	P value
Age group				
Children	3.4	(11/326)	0.64 (0.29–1.29)	0.231
Young adults	4.9	(46/930)	Reference	NA
Elderly	4.4	(5/113)	0.87 (0.27–2.30)	0.795
Sex				
Male	4.8	(58/1,199)	3.02 (1.02–12.98)	0.078
Female	2.4	(4/170)	Reference	NA
Season				
January–March	5.6	(29/517)	1.33 (0.58–3.38)	0.521
April–June	3.7	(11/297)	1.03 (0.38–2.91)	0.953
July–September	4.5	(14/314)	1.26 (0.49–3.46)	0.642
October–December	3.3	(8/241)	Reference	NA
Time of day				
00:00–07:59	0.0	(0/31)	NA	NA
08:00–15:59	4.6	(44/950)	0.86 (0.45–1.70)	0.650
16:00–23:59	4.6	(16/346)	Reference	NA
Injury site (AIS 3+)				
Head/neck (+)	8.3	(51/618)	6.14 (2.61–15.52)	<0.001
(-)	1.5	(11/751)	Reference	NA
Thorax (+)	6.1	(19/310)	2.80 (1.37–5.61)	0.004
(-)	4.1	(43/1,059)	Reference	NA
Abdomen (+)	1.4	(2/139)	1.38 (0.20–6.02)	0.700
(-)	4.9	(60/1,230)	Reference	NA
Pelvis/lower-extremity (+)	1.5	(1/65)	0.51 (0.02–3.28)	0.559
(-)	4.7	(61/1,304)	Reference	NA
Spine (+)	1.8	(8/446)	0.40 (0.15–1.01)	0.061
(-)	5.9	(54/923)	Reference	NA
Maximum AIS severity	-	-	6.84 (4.11-11.72)	<0.001

415 OR, odds ratio; CI, confidence interval; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale.

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417 **Table 3.** Patient characteristics of severe sports-related injury by age group

	≤11 years		12–14 years		15–17 years		18-64 years		≥65 years	
	Childhood		Young teens		Teenagers		Young adults		Elderly	
Characteristics	n=63		n=82		n=181		n=930		n=113	
Age, median, Q1-Q3	9	7-10	13	13-14	16	15-17	35	24-46	69	67-73
Male sex, n (%)	43	(68.3)	68	(82.9)	170	(93.9)	818	(88.0)	100	(88.5)
Season, n (%)										
January–March	19	(30.2)	25	(30.5)	34	(18.8)	387	(41.6)	52	(46.0)
April–June	19	(30.2)	17	(20.7)	57	(31.5)	182	(19.6)	22	(19.5)
July–September	11	(17.5)	23	(28.0)	57	(31.5)	205	(22.0)	18	(15.9)
October–December	14	(22.2)	17	(20.7)	33	(18.2)	156	(16.8)	21	(18.6)
Time of day										
00:00–07:59	0	(0.0)	0	(0.0)	7	(3.9)	20	(2.2)	4	(3.5)
08:00–15:59	40	(63.5)	48	(58.5)	111	(61.3)	658	(70.8)	93	(82.3)
16:00–23:59	20	(31.7)	34	(41.5)	56	(30.9)	226	(24.3)	10	(8.8)
Missing	3	(4.8)	0	(0.0)	7	(3.9)	26	(2.8)	6	(5.3)
Tertiary-care center	43	(68.3)	55	(67.1)	120	(66.3)	646	(69.5)	65	(57.5)
Injury site (AIS 3+), n (%)										
Head/neck	52	(82.5)	50	(61.0)	90	(49.7)	379	(40.8)	47	(41.6)
Thorax	5	(7.9)	7	(8.5)	14	(7.7)	252	(27.1)	32	(28.3)
Abdomen	7	(11.1)	15	(18.3)	30	(16.6)	85	(9.1)	2	(1.8)
Pelvis/lower-extremity	0	(0.0)	1	(1.2)	1	(0.6)	54	(5.8)	9	(8.0)
Spine	3	(4.8)	15	(18.3)	60	(33.1)	319	(34.3)	49	(43.4)
Maximum AIS severity, median, Q1-Q3	4	4-4	4	4-4	4	4-4	4	4-4	4	4-4
ISS, median, Q1-Q3	16	16-23	16	16-25	16	16-18	17	16-25	17	16-25
Shock on arrival, n (%)	3	(4.8)	3	(3.7)	3	(1.7)	30	(3.2)	5	(4.4)
Out-of-hospital cardiac arrest, n (%)	1	(1.6)	1	(1.2)	0	(0.0)	11	(1.2)	3	(2.7)
In-hospital mortality, n (%)	5	(7.9)	0	(0.0)	6	(3.3)	46	(4.9)	5	(4.4)

418 AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

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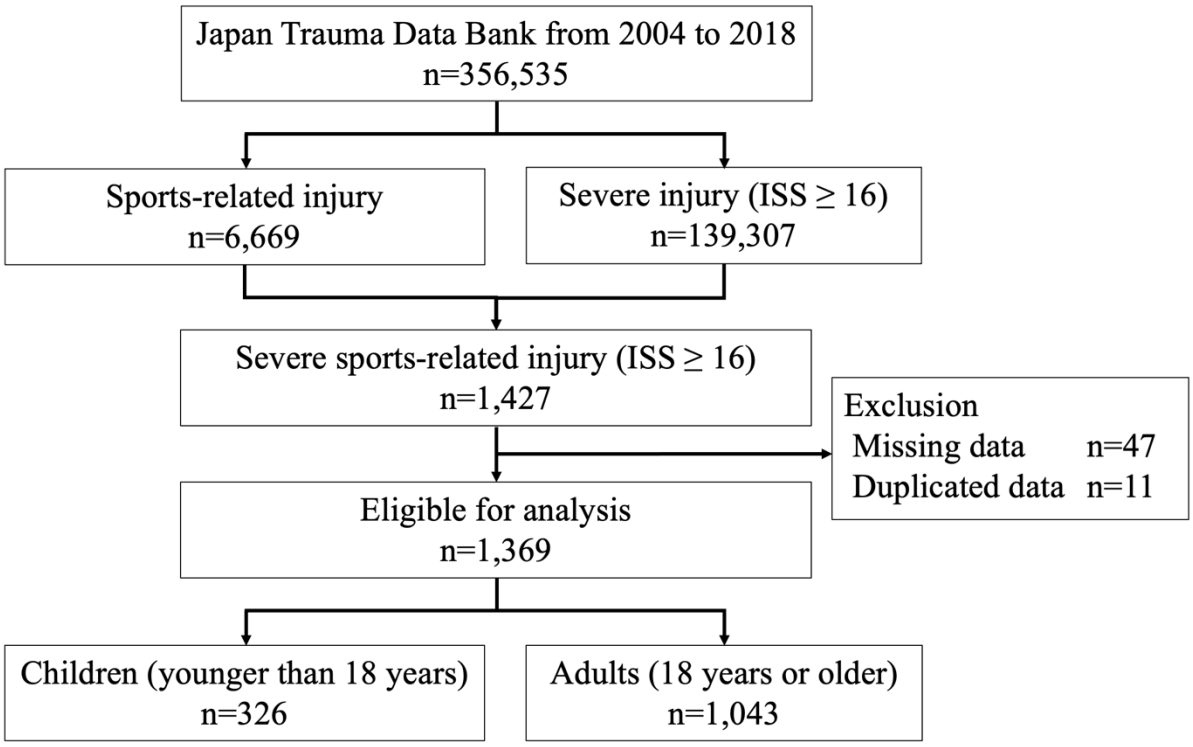

Fig. 1. Patient flow

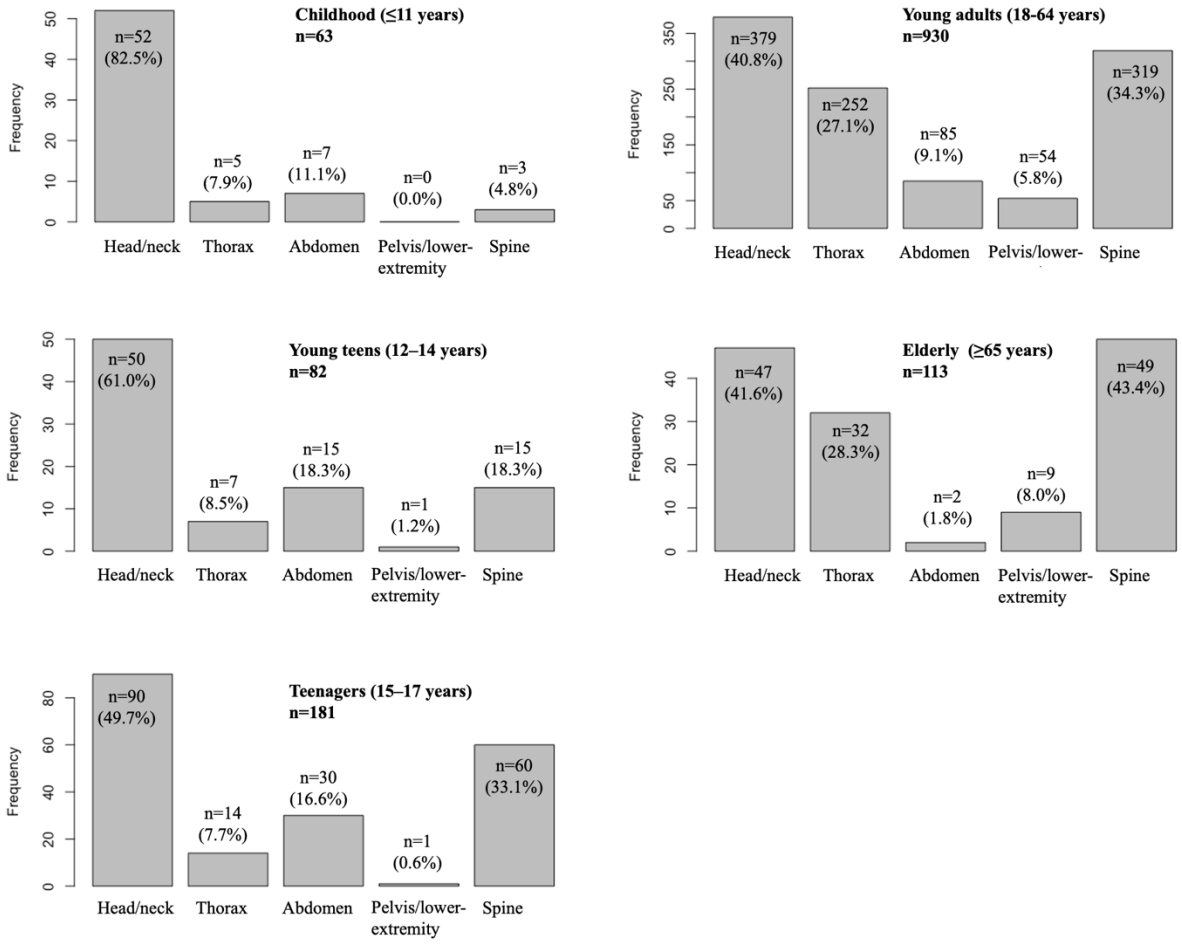

Fig. 2. Injury sites (AIS 3+) of severe sports-related injury by age group