의학박사 학위논문

소아/청소년 외상성 손상 환자의 특성 및 추이 변화에 대한 빅데이터 연구

A big data study about the characteristics and trends of traumatic injuries in children and adolescents

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서울대학교 대학원
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이 논문을 의학과 박사 학위논문으로 제출함

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A big data study about the characteristics and trends of traumatic injuries in children and adolescents

by

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Abstract

Background: Traumatic injury is a major cause of impairment or death in child/adolescent period. Traumatic injuries of children and adolescents are caused by various physical activities such as sports and leisure in various places such as playgrounds, schools, parks, etc. These physical activities are different according to ages, social atmosphere, and culture. Thus, individual countries need individualized efforts to prevent such impairments, and it must be constantly updated over time. This study analyzed the local and national incidence and characteristics of pediatric traumatic injuries requiring emergency department (ED) visits.

Materials and methods: Two different datasets were retrospectively reviewed, one from a single institute (a level I pediatric trauma center) and the other from a nationwide sample which was randomly generated from the claims records of the National Health Insurance. Patients aged <15 years who were identified with an S-code (traumatic injury) between 2006 and 2015 were included. The incidences and characteristics of injuries were investigated using both datasets, and detailed information regarding the injury environments was additionally investigated using the single-institutional data.

Results: The single-institutional and nationwide-sample datasets included 39,228 and 35,064 patients, respectively. The incidence of pediatric traumatic injuries increased despite the declining pediatric population size. The proportion of indoor playground (kids' cafe) and trampoline-related injuries

increased rapidly during the study period. The most commonly injured body part was the head, followed by upper extremities distal to the elbows (elbow to hand) and lower extremities distal to the knee (knee to foot). Injuries of the trunk or proximal extremities such as the shoulders or hips were rare. For preschoolers (<5 years old), the most common injuries were low-energy injuries of the head. As children grew older (≥5 years old), the injury rates of the lower extremities, the proportion of fractures, and the frequency of injuries outside the home increased, and seasonal variation (peak incidence in May and June) became clear. Visits to EDs peaked between 7 pm and 10 pm during the day, and they were more frequent on holidays.

Conclusions: The present results will help to establish education programs and preventive measures to improve children's safety. The increased frequency of pediatric traumatic injuries may be partially due to the spread of indoor playgrounds and installation of trampolines. More strict protective guidelines for their use are needed. To prevent traumatic injuries in children, it may be more effective to wear protective gear covering the head and distal extremities (distal to elbow/knee) rather than the trunk or proximal extremities. In particular, simple clothing such as caps could prevent many injuries in preschoolers. For children aged ≥5 years, protective guidelines for outdoor sports/leisure activities are required. Policies increasing medical support for pediatric trauma in EDs during holidays and evening hours should be considered.

Keywords: trauma; injury; child; emergency

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Introduction

Traumatic injuries are a major cause of impairment or death in children (Alonge et al., 2016). These injuries occur in various places during various activities (Johnston and Ebel, 2013) and change in their patterns over time (Booth et al., 2015, Centers for Disease and Prevention, 2007, Eithsdottir et al., 2008, Salmon et al., 2005). For example, sports participation is promoted to increase physical activity among children in most developed countries (Felfe et al., 2016, Strong et al., 2005), and participation in sports and leisure activities is increasing among this population (Eithsdottir et al., 2008, Landry and Driscoll, 2012, Salmon et al., 2005). By contrast, other activities in daily life, such as walking, tend to decrease (Centers for Disease and Prevention, 2007, McDonald et al., 2011, Salmon et al., 2005). Therefore, a comprehensive survey of pediatric traumatic injuries that is constantly updated is needed.

A substantial proportion of pediatric traumatic injuries is preventable (Johnston and Ebel, 2013); therefore, many countries are using strategies, including educational programs, to prevent these (Pearson et al., 2012). Although prevention of injuries in each country based on investigations performed in each country is likely to be more effective, few countries with a specific nationwide surveillance system have reported comprehensive studies (Hashikawa et al., 2015). Instead, the results of a comprehensive nationwide study performed in some specific countries are likely to be applicable to many

other countries with similar socioeconomic and environmental conditions, as general lifestyles and medical environments become increasingly similar globally (Alonge et al., 2016). Nevertheless, there is still a lack of diversity of a socioeconomic and environmental statuses of the countries where the studies are performed.

To obtain more reliable and accurate data, a large sample size is required. Nationwide databases of claim records are an adequate solution for this problem, but lack detailed information about the injury environments. Conversely, institutional data based on single or multiple hospitals or institutions, can provide more detailed information about the injury environments, but lack representativeness. Therefore, a complementary approach using both types of data is necessary.

This study investigated the incidence, characteristics, and trends of pediatric traumatic injuries to facilitate the establishment of preventive measures, such as educational programs, to improve the safety of children. For this purpose, we analyzed and compared both nationwide-sample cohort and single-institutional data.

Materials and methods

Datasets

Two different databases were retrospectively reviewed for this study; both were established on the basis of the International Classification of Diseases version 10. The present study protocol was reviewed and approved by the Institutional Review Board of the Asan Medical Center, Seoul, South Korea (approval no. 2017-0384).

1. Nationwide-sample data

Nationwide-sample data was obtained from the Korean National Health Insurance Sharing Service (NHISS). The Korean National Health Insurance Program covers the entire Korean population (97% of the population has health insurance and 3% has medical aid), and its database has been used for many epidemiological studies (Gong et al., 2009, Kang et al., 2010, Park et al., 2013, Shin et al., 2016). From the database, NHISS has released random nationwide-sample cohort data that are stratified according to age, sex, region, and other variables annually since 2002 (http://nhiss.nhis.or.kr). The data consist of the claim records of approximately 1 million patients each year (Shin et al., 2016). In the released data, age is categorized in 5-year increments to avoid revealing sensitive patient information.

2. Single-institutional data

Our hospital has a dedicated pediatric emergency department (ED), which was opened in December 2010; prior to this, pediatric patients were treated in the

same ED as adult patients. A biomedical research system is available at our hospital, which includes a search function that allows specified keywords to be identified in the electronic medical records (Shin et al., 2013, Shin et al., 2015).

Patients

1. Nationwide-sample data

Cases released in the NHISS dataset between January 1, 2006 and December 31, 2015 were assessed for eligibility. Patients aged <15 years who were identified with an S-code diagnosis (denoting traumatic injury) and initially treated by an emergency medicine specialist were included. Of 10,114,909 released cases, 35,064 (0.3%) were included in the analyses.

2. Single-institutional data

Patients aged <15 years who visited our ED over the same 10-year period as the nationwide-sample data and who were identified with an S-code diagnosis were included in the single-institutional dataset. A total of 39,228 patients were included in the analyses.

The number of included patients from each data source per year and corresponding national annual population statistics of South Korea are presented in Table 1.

Investigated variables

From the NHISS dataset, sex, age group (0–4, 5–9, or 10–14 years), medical provider department (e.g., emergency medicine, orthopedic surgery, or internal

Table 1. The numbers of pediatric traumatic injury cases in the NHISS and single-institutional data, and national population statistical data by year

Year	NHISS data		Single-institutional data	National statistical data†	
	Number of released cases*	Number of included cases**	Number of included cases**	Total Korean population	Korean population aged 0–14 years (%)
2006	996,393	2,421 (2,325.5 – 2,519.4)	2,560	48,438,292	8,979,585 (18.5%)
2007	1,005,549	2,977 (2,871.0 – 3,085.9)	2,176	48,683,638	8,714,382 (17.9%)
2008	1,008,693	3,150 (3,040.9 – 3,262.0)	1,971	49,054,708	8,478,823 (17.3%)
2009	1,012,695	3,406 (3,292.6 – 3,522.3)	2,973	49,307,835	8,229,264 (16.7%)
2010	1,013,299	3,690 (3,571.9 – 3,811.0)	2,704	49,554,112	7,979,439 (16.1%)
2011	1,013,297	3,807 (3,687.0 – 3,929.9)	3,669	49,936,638	7,771,460 (15.6%)
2012	1,015,567	3,779 (3,659.5 – 3,901.4)	4,940	50,199,853	7,577,231 (15.1%)
2013	1,015,049	3,993 (3,870.1 – 4,118.8)	5,558	50,428,893	7,392,237 (14.7%)
2014	1,017,343	4,136 (4,010.9 – 4,264.0)	6,552	50,746,659	7,213,693 (14.2%)
2015	1,017,024	3,705 (3,586.7 – 3,826.3)	6,125	51,014,947	7,029,883 (13.8%)
Total	10,114,909	35,064	39,228	497,365,575	79,365,997 (16.0%)

NHISS, National Health Insurance Sharing Service.

*Approximately 1 million cases are released by NHISS each year.

**Only patients aged <15 years who received an S-code diagnosis at emergency departments were included. The ranges in parentheses mean 95% confidence intervals.

†Data were obtained from the Korean Statistical Information Service (http://kosis.kr/index/index.do).

medicine), diagnostic code, and claim date were investigated. For patients with >1 claim record with an S-code, only the first entry was included.

From the single-institutional data, sex, age, diagnostic code, claim date, date of ED visit, place of injury (location where the injury occurred, classified as home, public place, school, restaurant, medical center, and others), and specific circumstances of the injury were investigated. For patients with >1 claim record with an S-code, only the first entry was included, and the age at the earliest claim was adopted.

Trends over time and characteristics of the injuries were investigated using both datasets; the type of injury and affected body part were determined using diagnostic codes. The timing of the ED visit (e.g., month, weekday, holiday) was determined using the claim date. In addition, detailed data about the injury environments were investigated using the single-institutional dataset; specific circumstances of the injury were evaluated using the following terminology: outdoor playground; kids cafe (indoor playground); school; private educational institute; trampoline; martial arts, such as taekwondo (Korean martial art), kendo (Japanese fencing), judo, or kung fu; sports such as skiing, snowboarding, sledding, or skating; and the use of specific equipment such as slides, swings, scooters, or wheeled sneakers. To select the appropriate term for each injury environment, and to cover the possibility of common spelling errors, the search terms were selected after reviews of a random sample of 1,000 cases.

Data analyses

The annual incidence rates per 1 million claim cases each year were presented for the NHISS data. To determine age-specific standardization by year, data on the entire Korean population in 2006, which were available from the Korean Statistical Information Service (http://kosis.kr), were established as the standard population.

A linear regression model was used to evaluate the trends in incidences by year. The incidences/incidence rates according to the year were used to predict the incidences in the near future (till 2030) by curve estimation methods. Statistical analyses were conducted using SPSS for Windows (version 21; IBM Co., Armonk, NY, USA) and p-values <0.05 were considered significant.

Results

Comparisons between the NHISS and single-institutional data

Table 2 shows demographic comparisons between the NHISS and single-institutional data. There were no significant differences in sex, age distribution, injured body part (Fig 1A), injury type (Fig 1B), and visit pattern between the datasets.

Fig. 1a. Comparisons between the single-institutional and NHISS data: Injured body part. In both the Korean National Health Insurance Sharing Service and single-institutional data, the most commonly injured body part was the head, followed by the upper extremities distal to the elbow (that is, the elbow to hand) and the lower extremities distal to the knee (that is, the knee to foot). Injuries of the trunk or proximal extremities such as the shoulders or hips were rare.

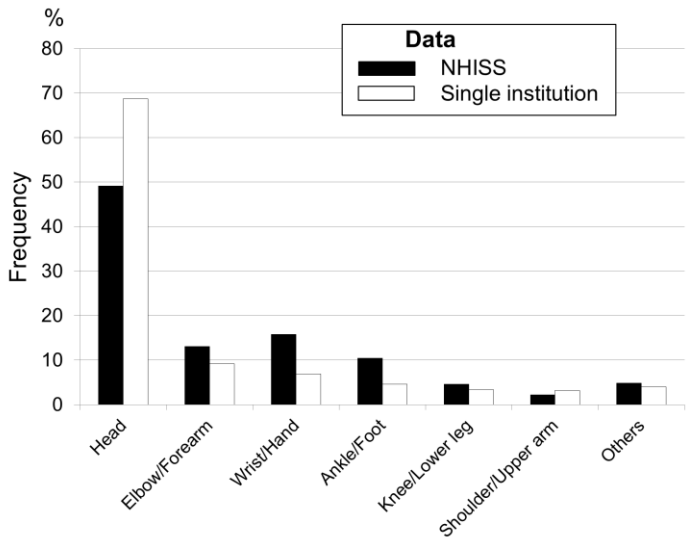


Fig. 1b. Comparisons between the single-institutional and NHISS data: Injury type. Low-energy injuries such as open wounds or superficial injuries were most common in both datasets.

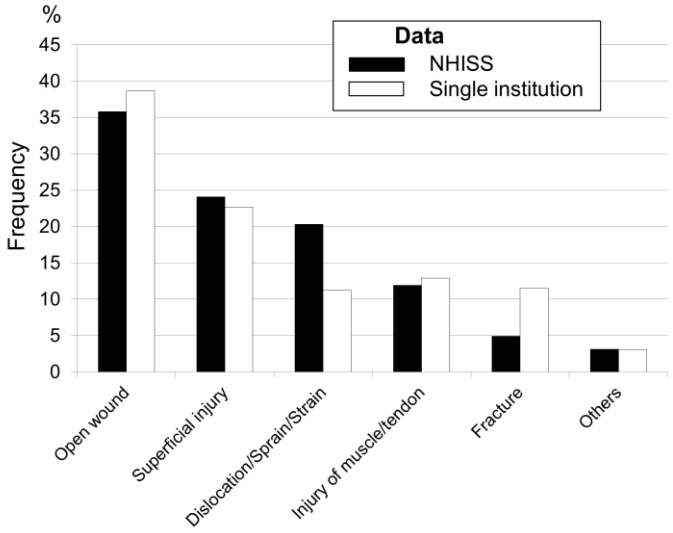


Table 2. Comparisons between the single-institutional and NHISS data

	Single-institutional data	NHISS data
Sex, n (%)		
Male	24,640 (62.8%)	21,644 (61.7%)
Female	14,588 (37.2%)	13,420 (38.3%)
Age, n (%)		
0–4 years	24,700 (63.0%)	17,479 (49.8%)
5–9 years	9,204 (23.5%)	10,272 (29.3%)
10–14 years	5,316 (13.6%)	7,313 (20.9%)
Injured body part, n (%)		
Head	26,931 (68.7%)	17,230 (49.1%)
Wrist/hand	2,708 (6.9%)	5,544 (15.8%)
Elbow/forearm	3,616 (9.2%)	4,595 (13.1%)
Ankle/foot	1,798 (4.6%)	3,640 (10.4%)
Knee/lower leg	1,337 (3.4%)	1,619 (4.6%)
Shoulder/upper arm	1,260 (3.2%)	756 (2.2%)
Others	1,578 (4.0%)	1,680 (4.8%)
Injury type, n (%)		
Open wound	15,191 (38.7%)	12,548 (35.8%)

Superficial injury	8,890 (22.7%)	8,455 (24.1%)
Dislocation/sprain/strain	4,399 (11.2%)	7,107 (20.3%)
Injury of muscle/tendon	5,049 (12.9%)	4,171 (11.9%)
Fracture	4,521 (11.5%)	1,702 (4.9%)
Others	1,178 (3.0%)	1,081 (3.1%)
Number of visits by month, n (%)		
January–February	4,933 (12.6%)	4,765 (13.6%)
March–April	6,540 (16.7%)	5,953 (17.0%)
May–June	7,465 (19.0%)	7,211 (20.6%)
July–August	7,172 (18.3%)	6,246 (17.8%)
September–October	7,285 (18.6%)	5,859 (16.7%)
November–December	5,833 (14.9%)	5,030 (14.3%)
Injuries by day of the week, n (n/day)		
Weekday	24,517 (9.4/day)	20,123 (7.7/day)
Weekend	14,711 (14.1/day)	14,941 (14.3/day)
Ratio of weekend/weekday injuries per day	1.50	1.86
Injuries by day of the year, n (n/day)		
Working day	22,992 (9.2/day)	18,407 (7.4/day)
Holiday	16,236 (14.1/day)	16,657 (14.5/day)
Ratio of holiday/working day injuries per day	1.53	1.96

NHISS, National Health Insurance Sharing Service. There were no significant differences in the characteristics between the datasets.

Changes over time in the NHISS and single-institutional data

Although the proportion of children aged 0–14 years in the overall Korean population gradually declined during the study period, the frequency of traumatic injuries tended to increase over time in both datasets (β=0.877, p=0.001 in the NHISS dataset and β=0.933, $p < 0.001$ in the single-institutional data; Figs 2a, b and c). The incidences decreased abruptly in 2015 in both datasets. When the incidence rates of the NHISS data were standardized to the national population in 2006 (Table 1), the rate of increase was accelerated (β=0.964, $p < 0.001$; Fig 2d).

Fig. 2a. Korean National Health Insurance Sharing Service (NHISS) data for the injury incidence rate per 1 million claim cases according to year. The incidence rate tended to increase during the 10-year study period (β=0.877, p=0.001). The ranges marked by bars mean 95% confidence intervals.

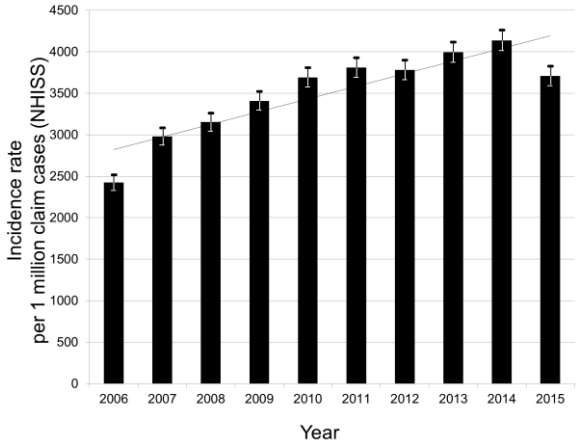


Fig. 2b. Single-institutional data for visiting patients by year. The number of injured patients tended to increase over the study period (β=0.933, $p < 0.001$) with more rapid changes occurring after 2010, which coincides with the opening of a pediatric emergency center in December of that year.

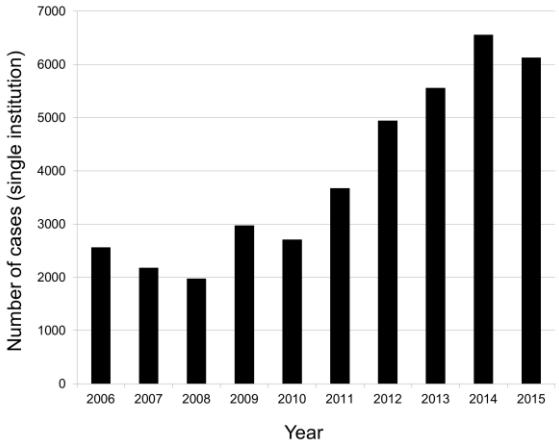


Fig. 2c. NHISS data weighted for age and body part. When the numbers of cases of single-institutional data were weighted for age and body part using the NHISS data, there was a greater increase in the single-institutional data.

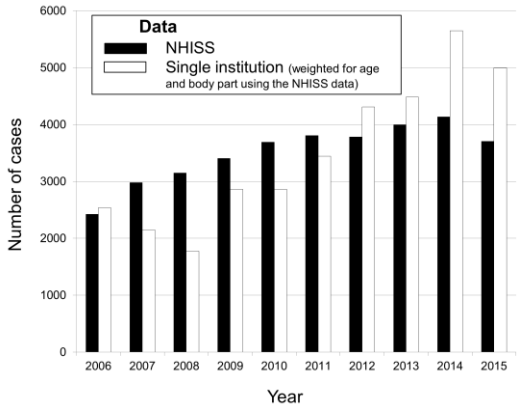
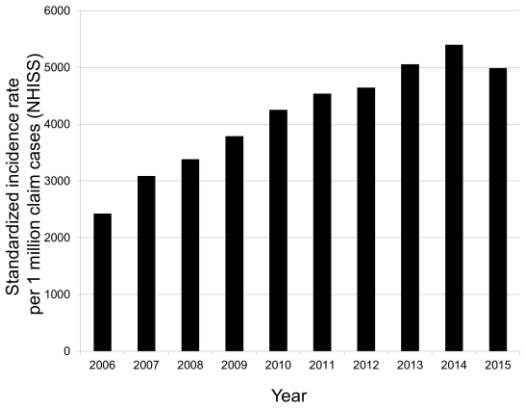


Fig. 2d. NHISS data for the standardized injury incidence rate per 1 million claim cases by year. Although there appeared to be a greater increase in the single-institutional data in Fig 2c, the rate of increase in the NHISS data became more rapid after standardization to the population composition in 2006 (β=0.964, $p < 0.001$). Despite a decreased proportion of children aged 0–14 years, the injury incidence rate increased over time. Therefore, the rate of pediatric traumatic injuries may have increased more rapidly than assumed.



Detailed data about the injury environments (by single-institutional data)

We examined the injury data in the single-institutional cohort on the basis of the affected body part (Table 3), injury type (Table 4), diagnostic code (Table 5), place of injury (Fig 3a), and ED visit patterns by month (Fig 3b). The most common time of ED visits was 7–10 pm (Fig 3c). Among the variables that were investigated regarding the injury environments, the frequencies of indoor playground and trampoline-related injuries increased rapidly during the study period (Fig 4).

Fig. 3a. The single-institutional data: place of injury by age. The home was the most common location where injury occurred in young children. As age increased, the injury rates outside the home also increased.

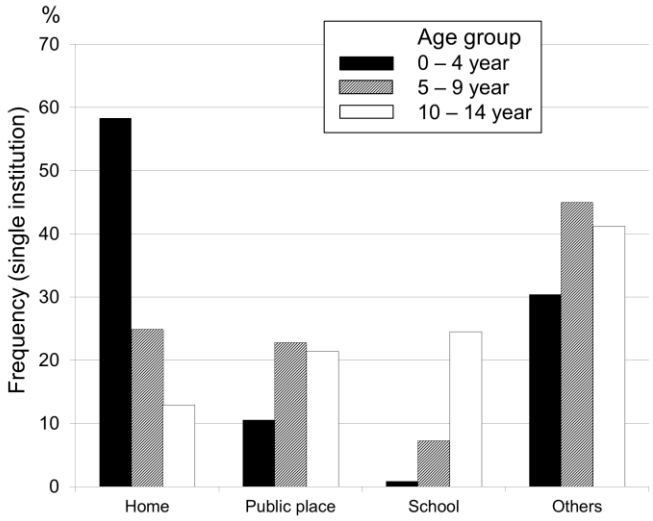


Fig. 3b. The single-institutional data: Monthly visit frequencies by age. The differences in the frequencies of emergency department visits by month became

more apparent as age increased. For older children, the visit frequency peaked in May and June, which is a period suitable for outdoor activities. By contrast, the frequency of visits was lowest during winter.

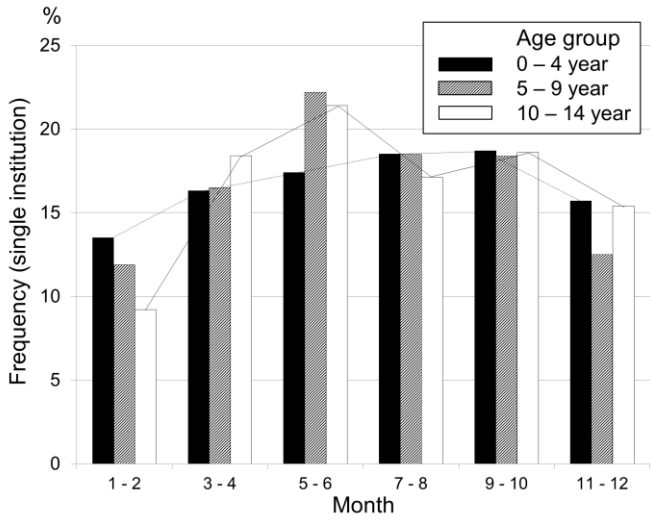


Fig. 3c. The single-institutional data: Time of emergency department visits. The most common time when emergency departments were visited was between 7 and 10 pm.

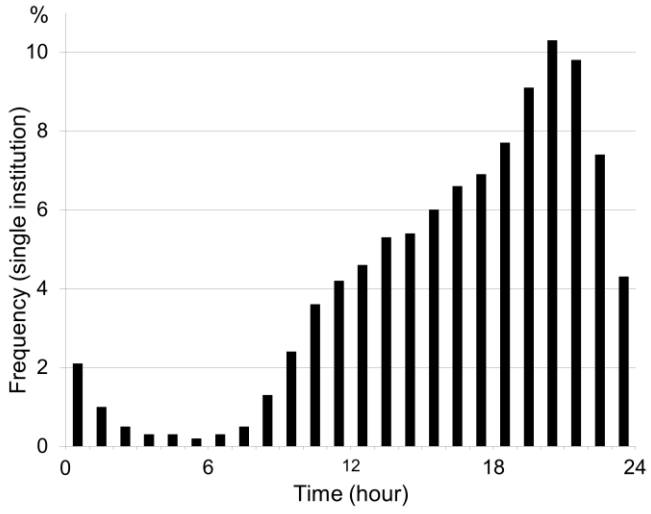


Table 3. Single-institutional data regarding injured body parts by age

Age group (years)	Order of frequency			
	1st	2nd	3rd	4th
0	Head	Elbow/forearm †	Wrist/hand †	Shoulder/upper arm
	2759 (82.2%)	281 (8.4%)	151 (4.5%)	77 (2.3%)
1–2	Head	Elbow/forearm †	Wrist/hand †	Ankle/foot ‡
	9944 (73.4%)	1524 (11.2%)	968 (7.1%)	429 (3.2%)
3–4	Head	Elbow/forearm †	Wrist/hand †	Ankle/foot ‡
	5480 (70.3%)	805 (10.3%)	466 (6.0%)	306 (3.9%)
5–6	Head	Elbow/forearm †	Ankle/foot ‡	Wrist/hand †
	3107 (66.7%)	330 (7.1%)	305 (6.6%)	263 (5.6%)
7–8	Head	Ankle/foot ‡	Wrist/hand †	Elbow/forearm †
	2098 (63.7%)	223 (6.8%)	220 (6.7%)	195 (5.9%)
9–10	Head	Knee/lower leg ‡	Wrist/hand †	Ankle/foot ‡
	1317 (56.6%)	199 (8.6%)	191 (8.2%)	179 (7.7%)
11–12	Head	Wrist/hand †	Knee/lower leg ‡	Ankle/foot ‡
	1103 (51.0%)	248 (11.5%)	183 (8.5%)	180 (8.3%)
13–14	Head	Knee/lower leg ‡	Wrist/hand †	Elbow/forearm †
	1123 (54.0%)	208 (10.0%)	201 (9.7%)	145 (7.0%)
Total	Head	Elbow/forearm †	Wrist/hand †	Ankle/foot ‡

	26931 (68.7%)	3616 (9.2%)	2708 (6.9%)	1798 (4.6%)

The head was the most frequently injured body part, whereas the trunk and proximal extremities were rarely injured across all age groups. Upper extremity injuries distal to the elbow (†) were more frequent than lower-extremity injuries distal to the knee (‡) in younger children, but became less frequent in older children. Data are presented as n (%).

Table 4. Single-institutional data regarding injury type by age

Age group (years)	Order of frequency			
	1st	2nd	3rd	4th
0	Superficial injury	Muscle/tendon injury	Open wound	Dislocation/sprain/strain
	1065 (31.7%)	1016 (30.3%)	555 (16.5%)	328 (9.8%)
1–2	Open wound	Superficial injury	Dislocation/sprain/strain	Muscle/tendon injury
	6104 (45.0%)	3080 (22.7%)	1841 (13.6%)	1545 (11.4%)
3–4	Open wound	Superficial injury	Dislocation/sprain/strain	Muscle/tendon injury
	3522 (45.2%)	1641 (21.0%)	937 (12.0%)	816 (10.5%)
5–6	Open wound	Superficial injury	Fracture	Muscle/tendon injury
	1971 (42.3%)	1025 (22.0%)	633 (13.6%)	473 (10.2%)
7–8	Open wound	Superficial injury	Fracture	Muscle/tendon injury
	1286 (39.0%)	701 (21.3%)	551 (16.7%)	371 (11.3%)
9–10	Open wound	Superficial injury	Fracture	Muscle/tendon injury
	729 (31.3%)	520 (22.4%)	497 (21.4%)	303 (13.0%)
11–12	Fracture	Open wound	Superficial injury	Muscle/tendon injury
	588 (27.2%)	556 (25.7%)	452 (20.9%)	265 (12.3%)
13–14	Fracture	Open wound	Superficial injury	Muscle/tendon injury
	620 (29.8%)	468 (22.5%)	406 (19.5%)	260 (12.5%)
Total	Open wound	Superficial injury	Muscle/tendon injury	Fracture

	15191 (38.7%)	8890 (22.7%)	5049 (12.9%)	4521 (11.5%)

Low-energy injuries (that is, superficial injuries such as abrasions or open wounds such as lacerations) were the most common injury type for children aged <5 years. Although fracture is a rare injury type in young children, it was relatively common in children aged >5 years and became the most common injury type in children aged >11 years (bold font). Data are presented as n (%).

Table 5. Single-institutional data regarding diagnostic codes by age

Age group (years)	Order of frequency					
	1st	2nd	3rd	4th	5th	6th
0	S06	S00	S01	S53	S02	S60
	1016 (30.3%)	937 (27.9%)	490 (14.6%)	267 (8.0%)	230 (6.9%)	62 (1.8%)
1–2	S01	S00	S06	S53	S60	S61
	5744 (42.4%)	2093 (15.4%)	1542 (11.4%)	1358 (10.0%)	515 (3.8%)	242 (1.8%)
3–4	S01	S00	S06	S53	S60	S42
	3274 (42.0%)	987 (12.7%)	811 (10.4%)	583 (7.5%)	242 (3.1%)	199 (2.6%)
5–6	S01	S00	S06	S52	S42	S02
	1745 (37.5%)	570 (12.2%)	461 (9.9%)	182 (3.9%)	178 (3.8%)	141 (3.0%)
7–8	S01	S00	S06	S02	S52	S42
	1096 (33.3%)	361 (11.0%)	358 (10.9%)	144 (4.4%)	143 (4.3%)	107 (3.2%)
9–10	S01	S06	S00	S02	S52	S42
	583 (25.1%)	285 (12.3%)	232 (10.0%)	125 (5.4%)	124 (5.3%)	91 (3.9%)
11–12	S01	S06	S00	S02	S52	S62
	409 (18.9%)	254 (11.8%)	187 (8.7%)	161 (7.5%)	136 (6.3%)	90 (4.2%)
13–14	S01	S02	S06	S00	S52	S82
	331 (15.9%)	250 (12.0%)	244 (11.7%)	185 (8.9%)	111 (5.3%)	79 (3.8%)
Total	S01	S00	S06	S53	S02	S60

	13672 (34.9%)	5552 (14.2%)	4971 (12.7%)	2357 (6.0%)	1423 (3.6%)	1138 (2.9%)

Open wounds (S01), superficial injuries (S00), and muscle/tendon injuries (S06) of the head were the most frequent injuries in nearly all age groups, but decreased with increasing age (72.8% at <1 year, 69.2% at 1–2 years, 65.1% at 3–4 years, and 36.5% at 13–14 years). Notably, superficial injuries and open wounds of the head comprised approximately one-half of all injuries in children aged <8 years (42.5% at <1 year, 57.8% at 1–2 years, 54.7% at 3–4 years, 49.7% at 5–6 years, and 44.3% at 7–8 years). S53, dislocation/sprain/strain of elbow/forearm; S02, fracture of head; S60, superficial injury of wrist/hand; S61, open wound of wrist/hand; S42, fracture of shoulder/upper arm; S52, fracture of elbow/forearm; S62, fracture of wrist/hand; S82, fracture of knee/lower leg. Data are presented as n (%).

Fig. 4a. The frequencies of indoor playground. The proportions of indoor playground injuries increased rapidly during the study period.

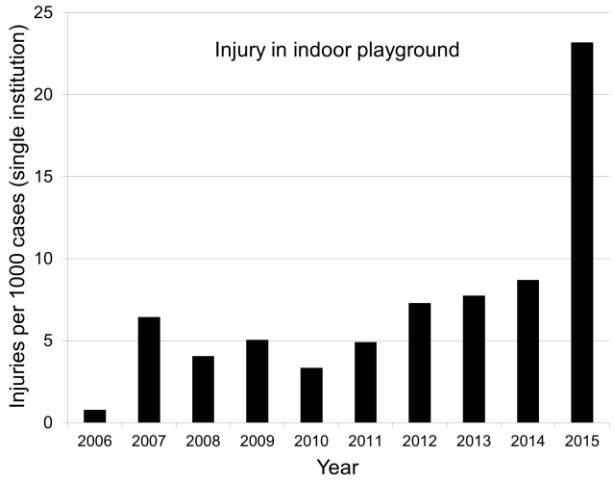
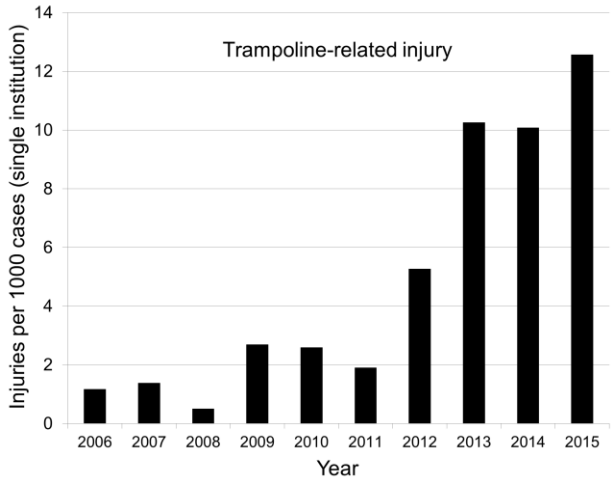


Fig. 4b. The frequencies of trampoline-related injuries. The proportions of trampoline-related injuries increased rapidly during the study period.



Estimated incidence rates according to trend

A linear regression model was used to evaluate the trends in incidences by year,

and the following equation was made (Fig 5). Since there was an abnormal decrease in 2015, the incidence rate for this year were excluded from the analysis. The decrease in 2015 may be explained by the outbreak of Middle East respiratory syndrome, when there was an attempt to reduce emergency department visits to prevent the spread of the virus (Jack, 2015).

$Y^3 = b_0 + b_1 \cdot X + b_2 \cdot X^2$

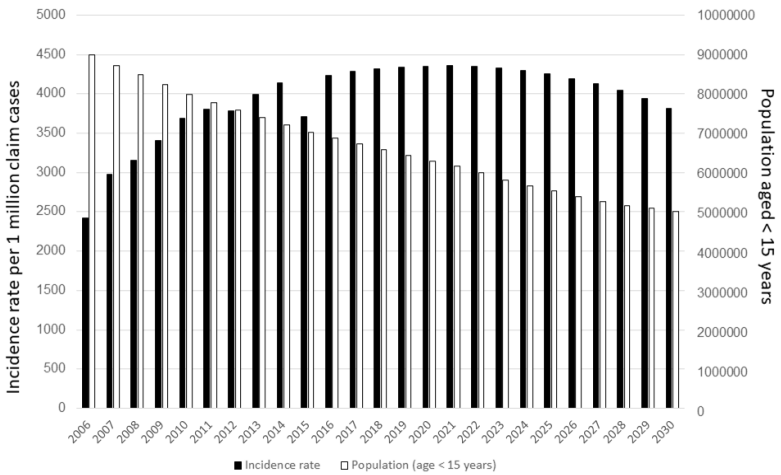
$b_0 = 15499002107$

$b_1 = 9143227551$

$b_1 = -311281930.9$

Y indicates incidence rate, and X indicates year

Fig. 5. The estimated incidence rates in the near future and the estimated number of population aged <15 years in Korea. The incidence rate of the pediatric traumatic injuries increases for some years, however, it may gradually decrease due to a significant decrease in the pediatric population.



Discussion

We analyzed and compared nationwide-sample (NHISS) and single-institutional data to investigate the characteristics and trends of pediatric traumatic injuries. The datasets each had advantages and disadvantages as follows: the NHISS data reflected national trends, but did not provide detailed information; by contrast, single-institutional data presented detailed information about the injury environments, but these were not representative nationally. We believe that our complementary approach using both datasets overcomes these disadvantages. The present results will help to establish preventive measures, such as educational programs, to improve the safety of children.

Comparisons between the datasets

The NHISS and single-institutional data were compared in Table 2. Both datasets revealed that injuries were more frequent in boys and younger children (aged 0–4 years). The most frequently injured body part was the head, followed by the upper extremities distal to the elbow (elbow to hand) and the lower extremities distal to the knee (knee to foot). The most common types of injury were open wounds and lacerations (Fig 1). Pediatric trauma patients visited the ED 1.5–2-fold more frequently on holidays and weekends than on working days and weekdays (Table 2). These results suggest that the injury/medical environments associated with pediatric trauma are relatively similar throughout

the country; therefore, the detailed results of single-institutional datasets could be generalized to national circumstances with adequate external validity.

Increasing frequency of injuries in children despite a declining pediatric population

South Korea has experienced rapid decreases in both mortality and fertility, which have contributed to increasing the population age (Dronina et al., 2016); consequently, the proportion of children (aged 0–14 years) among the whole population is decreasing (Table 1). However, the incidences of pediatric traumatic injury in both datasets increased over time (Fig 2). Therefore, the standardized NHISS data revealed more rapid increases than the unstandardized data. More effective preventive measures that are strictly adhered to are necessary to address the rapid growth in the incidence of pediatric traumatic injuries over the past 10 years.

The more rapid increases in the incidences of injury after 2011 in the single-institutional data might be partially attributable to the opening of a pediatric emergency center in December 2010.

To assess the cause of the rapid increase observed during the 10-year study period, we surveyed the environment at the time of injury. Among the surveyed variables, the proportions of indoor playgrounds and trampoline-related injuries increased rapidly (Fig 4). The increased number of trampolines in many indoor playgrounds or trampoline parks could be a contributing factor (Choi et al., 2018). Although trampolines are widely available in the US, the frequency of

trampoline-related injuries has somewhat declined, as guidelines for their use have become broadly acknowledged (Council on Sports et al., 2012). However, the frequency of trampoline-related injuries has continued to increase in many other countries (Ashby et al., 2015, Cheung et al., 2016, Konigshausen et al., 2014). Thus, the national promotion of guidelines to prevent trampoline-related injuries, especially in public areas, is necessary.

Commonly injured body parts

The head was the most frequently injured body part, followed by the upper extremities distal to the elbow and the lower extremities distal to the knee (Fig 1A). Although the frequency changed with age, the trunk and proximal extremities, such as the shoulder and hip, were rarely injured across all age groups (Tables 3 and 5). Therefore, to prevent traumatic injuries in children, it may be more effective to wear protective equipment that covers the head and the extremities distal to the elbow and knee, rather than the trunk or proximal extremities.

Characteristics of injuries in preschoolers

In children aged <5 years, the head was the most frequently injured body part followed by the upper extremities distal to the elbow (Table 3), and low-energy injuries (that is, superficial injuries such as abrasions or open wounds such as lacerations) were the most common injury type (Table 4). Indeed, superficial injuries and open wounds of the head comprised approximately one-half of all

injuries in children aged <8 years (Table 5). Therefore, many injuries could be prevented in this age group by wearing simple clothing that covers the head, such as a cap or hat.

The diagnostic code S53 (which denotes a dislocation, sprain, or strain of the elbow or forearm) was common in children aged <5 years, and may be explained in part by the high incidence of pulled elbows in this age group (Jongschaap et al., 1990, Welch et al., 2017).

Characteristics of injuries in children aged ≥ 5 years

The rate of lower-extremity injuries was higher in older children (Table 3). Foot and ankle injuries were more common in children aged <9 years, whereas knee and lower leg injuries were more common in those aged ≥ 9 years. However, these findings do not suggest that older children have a lower risk for foot and ankle injuries. The frequency of foot and ankle injuries was maintained consistently across the age groups, comprising 6%–8% of injuries in those aged 7 to approximately 12 years. Fracture was relatively common after the age of 5 years, and was the most common injury type in children aged >11 years (Table 4). Considering that fractures affecting the lower extremities are often associated with sports or leisure activities (Palmu et al., 2014, Su and Larson, 2015), findings suggest that lower-extremity injuries become more common as children grow older because of increased participation in such activities. This assumption is supported by the finding that older children exhibited an increased rate of injuries outside the home (Fig 3A) and a large increase in the

frequency of injuries during May and June, which are suitable months for outdoor activities in authors' country because there are many holidays and the temperature is adequate (Fig 3B).

Although a diagnostic code of S53 was relatively common in children aged <5 years of age, S52 (which denotes a fracture of elbow or forearm) was relatively common in older children (Table 5), probably as a result of increases in the supracondylar and lateral condylar humeral fractures in this age group (Houshian et al., 2001, Kang and Park, 2015, Khoshbin et al., 2014).

Timing of ED visits

Visits to the ED peaked between 7 and 10 pm (Fig 3C). This finding could indicate that pediatric injuries frequently occur in this period; however, it could also be a result of patients visiting the outpatient clinic rather than the ED during earlier periods (9 am to 5 pm) or be due to difficulties among parents in accessing healthcare facilities given the high proportion of young working couples in authors' country (http://www.index.go.kr/potal/main/EachDtlPageDetail.do?idx_cd=3037).

These same interpretations could be used to explain the higher number of visits on holidays and weekends in both datasets (Table 2). More research is needed to determine the cause underlying the increased frequency of visits during the evening or on holidays; however, it is clear that sufficient numbers of emergency medical personnel should be made available to attend to pediatric trauma cases during these busy periods.

Limitations

Some considerations and limitations should be noted when interpreting the results of the present study. First, the medical environments for trauma differ by country; therefore, it is difficult to determine whether these data are generalizable outside of South Korea. Nevertheless, as the general lifestyle and medical environment become more similar globally (Alonge et al., 2016), results of the present study are likely to become applicable to many countries with similar socioeconomic conditions to ours. Second, although the NHISS and single-institutional data were similar in many aspects, it is necessary to recognize the possibility of selection bias caused by referrals of more severe cases to our institute, which is a tertiary referral hospital. Third, there may be limitations regarding the use of sample data. The sample cohort used in the present study were randomly selected and stratified data reflecting approximately 1 million claims records per year; therefore, the sample data may not reflect medical utilization among the total population, and further comprehensive studies may be needed.

Conclusion

To investigate the characteristics and trends of pediatric traumatic injuries, we used a complementary approach including both nationwide-sample and single-institutional data. Based on the similarities between both datasets, the detailed results of the single-institutional data could be extended and applied nationally with adequate external validity. Despite the declining pediatric population, the incidence of pediatric traumatic injuries has increased, including the proportions of indoor playground and trampoline-related injuries. The increase of pediatric traumatic injuries may be partially a result of the increased availability of indoor playgrounds and installation of trampolines. Preventive guidelines have been published, but stricter adherences to their use would be needed. The most commonly injured body part was the head, followed by the upper extremities distal to the elbow (elbow to hand) and the lower extremities distal to the knee (knee to foot). Injuries of the trunk or proximal extremities such as the shoulders or hips were rare. To prevent traumatic injuries in children, it may be more effective to wear protective gear covering the head and extremities distal to the elbow or knee, rather than the trunk or proximal extremities. For preschoolers (aged <5 years), low-energy injuries of the head were most common; therefore, simple clothing such as caps could prevent many injuries in this age group. Among children aged ≥ 5 years, the rates of lower-extremity injuries, fractures, and injuries occurring outside the home increased,

and seasonal variation (peak incidence in May and June) became evident. Protective guidelines for outdoor sports and leisure activities are necessary for these children. Visits to the ED peaked between 7 and 10 pm, and on holidays and weekends. Policies to increase medical support for pediatric trauma in the ED during these periods should be considered. The present results could facilitate the establishment of preventive measures, such as educational programs, to improve the safety of children.

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국문 초록

목 적: 소아와 청소년에서 외상성 손상은 사망이나 장애의 주요 원인 중 하나이다. 이 시기의 외상성 손상은 놀이터나 학교, 공원 등 다양한 장소에서 스포츠나 레저 등 다양한 활동에 의해 발생한다. 이러한 소아/청소년의 신체 활동은 시대에 따라 다르고, 나이에 따라, 사회적 분위기에 따라, 문화에 따라 영향을 받는다. 따라서 국가마다 나이에 따른 손상에 대한 개별적인 접근 및 예방 노력이 필요하며, 이는 시간이 지나면서 사회의 환경에 따라 지속적으로 업데이트 되어야 한다. 이 연구에서는 응급실을 방문하는 우리나라 소아/청소년들의 외상성 손상의 특징 및 변화 양상을 분석하였으며, 단일 병원 데이터와 공공 데이터를 모두 활용하여 분석하였다.

대상 및 방법: 단일 병원의 소아 응급실을 방문하는 환자의 기록과 건강보험공단에서 매년 공개하는 개방 데이터를 각각 후향적으로 분석하였다. 2006 년부터 2015 년까지 응급실을 방문하여 S 코드(외상성 손상)의 진단명이 붙은 15 세 미만 환자들을 대상으로 하였다. 두 데이터에서 손상의 특성 및 발생빈도를 분석하여 비교하였고, 손상 당시의 구체적인 환경에 대해서는 단일 병원 데이터를 사용하여 추가 분석하였다.

결 과: 단일 병원 데이터에서는 39,228 명, 개방 데이터에서는 35,064 명이 분석에 포함되었다. 연구 기간 동안 소아 인구의 감소에도 불구하고 외상성 손상의 빈도는 증가하는 양상을 보였다. 키즈 카페에서의 손상과 트램폴린 관련된 손상의 비율이 뚜렷하게 증가하는 경향을 보였다. 가장 빈도가 높은 손상 부위는 머리였으며, 이후 팔꿈치 이하의 상지와 무릎 이하의 하지가 흔히 손상되는 부위였다. 반면에 체간이나 어깨/고관절 같은 상하지의 근위부 손상은 드물었다. 5 세 미만의 미취학 아동에서 가장 흔한 손상은 두부의 저에너지 손상이었다. 나이가 많아지면서 점차 하지 및 골절, 집 밖에서의 손상의 비율이 증가하였으며, 계절에 따른 차이 또한 나이가 많아지면서 뚜렷해지는 경향을 보였다. 평일 응급실 방문은 오후 7 시에서 10 시 사이가 가장 많았으며, 휴일에 평일보다 방문이 더 많았다.

결 론: 소아와 청소년에서 외상성 손상의 비율은 점차 증가하고 있다. 이중 일부는 키즈 카페와 트램폴린의 보급에 의한 영향이 의심되므로, 키즈 카페와 트램폴린 사용에서의 안전 수칙을 더 엄격히 지키려는 노력이 필요할 것이다. 외상성 손상을 예방하기 위해 머리와 사지 원위부를 보호하는 보호 장구가 체간이나 사지 근위부를 보호하는 것보다 훨씬 효과적일 것이다. 특히 미취학 아동에서는 모자 착용과 같은 간단한 방법만으로도 많은 손상을 예방할 수 있을 수 있다. 나이가 많아지면서 외부 활동이나 레저 활동 시의 안전 수칙이 손상 예방에 더 중요할 것으로 여겨진다. 소아/청소년 외상성 손상의 응급실 비율이

높아지는 저녁 시간대와 휴일에 이에 대한 의료적 지원을 늘리는 방안이 검토될 수 있을 것이다.

색인 단어: 외상; 손상; 소아; 응급

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