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Preventive Effects of Seat Belt on Clinical Outcomes for Road Traffic Injuries

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Proper seat belt use saves lives; however, the use rate decreased in Korea. This study aimed to measure the magnitude of the preventive effect of seat belt on case-fatality across drivers and passengers. We used the Emergency Department based Injury In-depth Surveillance (EDIIS) database from 17 EDs between 2011 and 2012. All of adult injured patients from road traffic injuries (RTI) in-vehicle of less than 10-seat van were eligible, excluding cases with unknown seat belt use and outcomes. Primary and secondary endpoints were in-hospital mortality and intracranial injury. We calculated adjusted odds ratios (AORs) of seat belt use and driving status for study outcomes adjusting for potential confounders. Among 23,698 eligible patients, 15,304 (64.6%) wore seat belts. Driver, middle aged (30-44 yr), male, daytime injured patients were more likely to use seat belts (all $P < 0.001$). In terms of clinical outcome, no seat belt group had higher proportions of case-fatality and intracranial injury compared to seat belt group (both $P < 0.001$). Compared to seat belt group, AORs (95% CIs) of no seat belt group were 10.43 (7.75-14.04) for case-fatality and 2.68 (2.25-3.19) for intracranial injury respectively. In the interaction model, AORs (95% CIs) of no seat belt use for case-fatality were 11.71 (8.45-16.22) in drivers and 5.52 (2.83-14.76) in non-driving passengers, respectively. Wearing seat belt has significantly preventive effects on case-fatality and intracranial injury. Public health efforts to increase seat belt use are needed to reduce health burden from RTIs.

Keywords: Mortality; Accident Prevention; Motor Vehicles; Seat Belts

INTRODUCTION

Road traffic injury (RTI) is one of top five causes of all-cause mortality globally, and the incidence is increasing as the number of vehicles increases (1,2). In Korea, the mortality rate from RTI was on the rise until the 2000s and started to decrease; however, it still accounted as the second leading cause of death among youth and the ninth in all ages in 2013 (3). RTI is predicted to result in more severe functional impairment as well as higher case-fatality compared to other blunt trauma (4). Even though several strategies to prevent RTI such as public campaign and legislation were implemented, the incidence and mortality of RTIs increased especially in developing countries (5).

Education, enforcement, and engineering are known to be highly effective in preventing injuries including RTI (6-10). Seat belt, when properly used, is accounted as one of the most effective modalities to save lives and reduce the extent and number of injuries (7-9). Proper seat belt use prevents 25%-50% of fatal injuries, 25%-45% of serious injuries, and 20%-25% of minor injuries (11). However, seat belt use remains low at 4% to 72% (12-14). According to the 2013 National Health Statistics of Korea, the seat belt use rates for male and female drivers continuously decreased since 2001 from 82.8% to 63.5% and 91.5% to 74.1%, respectively; for male and female front seat passengers, the use rates decreased from 76.3% to 51.7% and 80.5% to 61.5%, respectively (15).

Driving status and passenger seating positions are also associated with case-fatality and severe injury (16). It is known that front seat passengers have higher case-fatality from RTI (17); on the contrary, there is only minimal risk difference when both driver and the front seat passenger are belted (18). Moreover, rear seat passengers are less likely to die compared to front seat passengers; however, unbelted rear seat passengers are not only at increased risk, but also pose harmful effects on belted front seat passengers (16,19-21).

The seat belt use rates are different among drivers and non-driving passengers, and the clinical outcomes are affected by both of seat belt use and driving status. Studies comparing the preventive effects of seat belt on clinical outcomes between drivers and non-driving passengers are limited. We hypothesize that the preventive effects of seat belt on case-fatality and severe injury would be bigger in magnitude for drivers than for non-driving passengers among injured patients from RTI. This study aimed to describe the seat belt use among patients who sustained RTI, to evaluate the preventive effects of seat belt, and to compare the effects across drivers and non-driving passengers.

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MATERIALS AND METHODS

Study design and setting

This is an observational study using the Emergency Department based Injury In-depth Surveillance (EDIIS) database in Korea. The EDIIS is a nationwide, prospective database of injury patients visiting the emergency department (ED), which gathers injury-related information for planning national policy in injury prevention. The EDIIS project was organized and financially supported by the Korea Centers for Disease Control and Prevention (CDC). The Ministry of Health and Welfare designated EDs into three levels according to the resources and functional requirements; level 1 (n = 19) and level 2 (n = 110) EDs have more resources and better facilities for emergency care and must be staffed by emergency physicians 24 hr a day and 365 days a year.

Data source and collection

The EDIIS was designed based on the core dataset of the International Classification of External Causes of Injuries (ICECI) proposed by the World Health Organization. The database collects patients' demographic information, injury-related information, prehospital emergency medical service records, clinical findings, diagnostic assessment and medical treatment in the ED, ED disposition, and patient outcome after admission if the patient was admitted (22).

Primary surveillance and data collection was performed by general physicians, and most of the recorded information was supervised and corrected by emergency medicine physicians and trained research coordinators on a daily basis. All research coordinators were required to complete training prior to project participation and regularly input surveillance data into a web-based database system of the Korea CDC. The data was reviewed every month by the quality management committee of this project, who provided regular feedback to maintain the data quality.

Study population

The study population was all adult patients who sustained RTI in vehicle (drivers and non-driving passengers) and visited any of the 17 tertiary academic teaching hospitals' EDs (10 level 1 EDs and 7 level 2 EDs) between January 2011 and December 2012, excluding cases resulting from out-of-vehicle RTI, 10-or-more passenger vans, or had unknown information on seat belt use and/or clinical outcomes. Patients who visited EDs for recurrent complications after injury were not included in this study.

Main outcomes

The primary endpoint was in-hospital mortality, defined as death in ED or during initial admission resulting from the injury event regardless of the duration from injury to death, determined at discharge from ED or hospital. The secondary endpoint was intracranial injury, defined as diagnosis of ICD-10 code S06.1-S06.9 as recorded on discharge summary after ED and/or hospital admission. The tertiary endpoint was clinically important injury, defined as admission to general ward or intensive care unit or mortality in ED as results of the injury event, determined at discharge from ED.

Variables and measurements

The main exposure of interest was seat belt use, as detected by the EDIIS registry.

Driving was divided into two classes including drivers and non-driving passengers. We collected information on demographic factors (age, gender, and past medical history), injury-related factors (time of injury, day of injury, alcohol-related injury), prehospital factors (emergency medical services [EMS] use and time from injury to ED arrival), hospital factors (initial vital status and ED disposition), and clinical outcomes.

Statistical analysis

Descriptive analysis was performed to examine the distribution of the study variables; counts and proportions were used for categorical variables, and median and quartile values were used for continuous variables. Continuous variables were compared using the Wilcoxon rank sum test or Kruskal-Wallis test, and categorical variables were compared using the chi-square test.

Adjusted odds ratio (AOR) with 95% confidence intervals (95% CIs) of seat belt use for the study endpoints were calculated using multivariable logistic regression analysis with no seat belt use as reference. The adjusted model controlled for age, gender, past medical history (hypertension and diabetes melli-

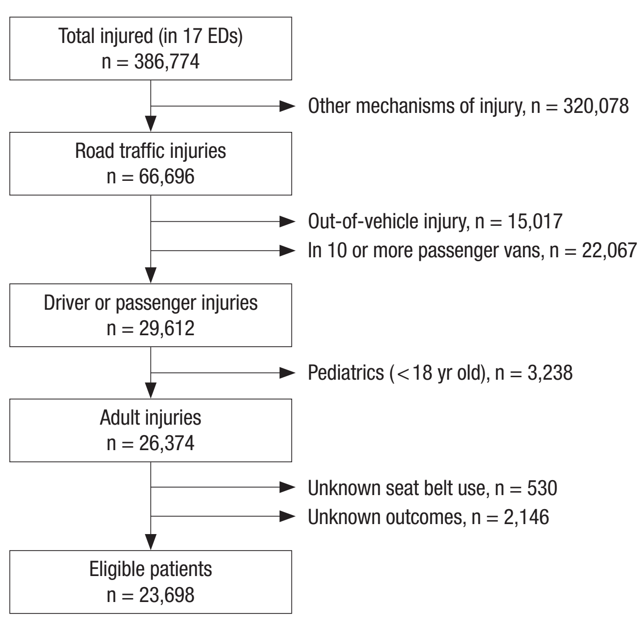

Fig. 1. Study population flow. ED, emergency department.

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tus), day and time of injury, alcohol use, and driving status.

To calculated the AOR (95% CIs) according to the driving status (driver and non-driving passenger), we developed an interaction model with an interaction term (seat belt use*driving status) as the final multivariable logistic regression model for the outcomes. All statistical analysis was performed using SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA). *P* values were based on a two-sided significance level of 0.05.

Table 1. Demographic findings and clinical outcomes by seat belt use

Parameters	Total		Seat belt group		No seat belt group		*P* value
	No.	%	No.	%	No.	%	
Total	23,698	100	15,304	64.6	8,394	35.4	
Driving status							< 0.001
Driver	14,465	61.0	11,091	72.5	3,374	40.2	
Non-driving passenger	9,233	39.0	4,213	27.5	5,020	59.8	
Age (yr)							< 0.001
19-29	5,761	24.3	3,308	21.6	2,453	29.2	
30-44	9,047	38.2	6,208	40.6	2,839	33.8	
45-64	7,259	30.6	4,854	31.7	2,405	28.7	
65-	1,631	6.9	934	6.1	697	8.3	
Median (IQR)	39 (30-51)		38 (28-51)		39 (31-51)		< 0.001
Gender							< 0.001
Female	11,171	47.1	6,998	45.7	4,173	49.7	
Past medical history							
Hypertension	679	2.9	398	2.6	281	3.3	0.001
Diabetes mellitus	338	1.4	197	1.3	141	1.7	0.015
Time of injury							< 0.001
Daytime (6 am-6 pm)	12,801	54.0	8,665	56.6	4,136	49.3	
Day of injury							0.012
Weekend	8,856	37.4	5,630	36.8	3,226	38.4	
Alcohol use	1,489	6.3	542	3.5	947	11.3	< 0.001
EMS use	10,629	44.9	6,084	39.8	4,545	54.1	< 0.001
Time from injury to ED arrival							< 0.001
Minute, median (IQR)	70 (40-251)		61 (37-240)		77 (41-274)		
Initial systolic blood pressure (mmHg)							< 0.001
0-89	341	1.4	121	0.8	220	2.6	
90-	18,358	77.5	11,692	76.4	6,666	79.4	
Unknown	4,999	21.1	3,491	22.8	1,508	18.0	
Heart rate per minute							< 0.001
0-59	488	2.1	268	1.8	220	2.6	
60-99	16,330	68.9	10,486	68.5	5,844	69.6	
100-	1,888	8.0	1,058	6.9	830	9.9	
Unknown	4,992	21.1	3,492	22.8	1,500	17.9	
Respiratory rate per minute							< 0.001
0-9	145	0.6	57	0.4	88	1.0	
10-29	18,461	77.9	11,714	76.5	6,747	80.4	
30-	72	0.3	35	0.2	37	0.4	
Unknown	5,020	21.2	3,498	22.9	1,522	18.1	
Initial mental status							< 0.001
Alert	19,083	80.5	12,282	80.3	6,801	81.0	
Verbal response	177	0.7	59	0.4	118	1.4	
Pain response	157	0.7	46	0.3	111	1.3	
Unresponsive	207	0.9	30	0.2	177	2.1	
Unknown	4,074	17.2	2,887	18.9	1,187	14.1	
ED disposition							< 0.001
Discharge	19,353	81.7	13,088	85.5	6,265	74.6	
Admission to ward	3,130	13.2	1,740	11.4	1,390	16.6	
Admission to ICU	1,028	4.3	444	2.9	584	7.0	
Death in ED	187	0.8	32	0.2	155	1.8	
Clinical outcome							
Case-fatality	297	1.3	58	0.4	239	2.8	< 0.001
Intracranial injury	607	2.6	257	1.7	350	4.2	< 0.001
Clinically important injury	4,345	18.3	2,216	14.5	2,129	25.4	< 0.001

IQR, interquartile range; EMS, emergency medical services; ED, emergency department; ICU, intensive care unit.

Ethics statement

The study was reviewed and approved by the institutional review board of Seoul National University Hospital (IRB No. 1103-152-357). Informed consent was waived and patient information was anonymized prior to analysis.

RESULTS

Seat belt use of road traffic injuries

Of 386,774 injured patients, 23,698 (6.1%) patients were eligible for study inclusion, excluding other mechanisms of injury (n = 320,078), out-of-vehicle injuries (n = 15,017), injuries occurring in 10-or-more passenger vans (n = 22,067), pediatric patients (n = 3,238), and patients with unknown information of seat belt use (n = 530) or clinical outcomes (n = 2,146) (Fig. 1).

Table 1 shows the demographic characteristics by seat belt use. Among 23,698 eligible patients, 15,304 (64.6%) were wearing seat belts. Driver, middle-aged (30-44 yr old), male, and daytime injury patients were more likely to wear seat belts (all P < 0.001). In terms of clinical outcomes, no seat belt group had a higher proportion of case-fatality, intracranial injury, and clinically important injury compared to seat belt group (all P < 0.001).

Table 2 shows the demographic characteristics by driving status. From 23,698 eligible patients, 14,465 (61.0%) were drivers. Among drivers, 76.7% (n = 11,091) were wearing seat belts, whereas 45.6% (n = 4,213) among non-driving passengers used seat belts (P < 0.001). In terms of clinical outcome, drivers group had a higher proportion of case-fatality and clinically important injury (both P < 0.001).

Multivariable logistic regression analysis

Compared to no seat belt group, the AOR (95% CI) of the seat belt group for case-fatality was 10.43 (7.75-14.04); 2.68 (2.25-3.19) for intracranial injury; and 2.19 (2.04-2.36) for clinical important injury, respectively. In comparison, the AOR (95% CI) of the driver group was 2.95 (2.21-3.94) for case-fatality; 1.34 (1.11-1.62) for intracranial injury; and 1.41 (1.30-1.53) for clinical important injury respectively, in reference to the non-driving passenger group (Table 3).

Multivariable logistic regression analysis with interaction term

In the interaction model, AORs (95% CIs) of seat belt use for case-fatality were 11.71 (8.45-16.22) in drivers and 5.52 (2.83-14.76) in non-driving passengers. When a driver did not wear seat belt, the odds for case-fatality was 11.71 times higher relatively to when a driver wore seat belt. Furthermore, when a non-driving passenger did not wear seat belt, the odds were 5.52 times higher compared to the odds of case-fatality in a seat belt-wearing non-driving passenger. In terms of intracranial injury, AORs (95% CIs) comparing the seat belt group and no seat belt group were 3.05 (2.47-3.75) in drivers and 2.06 (1.54-2.76) in non-driving passengers. In terms of clinically important injury, AORs (95% CIs) of seat belt group compared with no seat belt group were 2.64 (2.41-2.90) in drivers and 1.61 (1.43-1.81) in non-driving passengers (Table 4).

DISCUSSION

A nationwide injury surveillance data identified significant preventive effects of seat belt on case-fatalities, intracranial injuries, and clinically important injuries requiring hospital admission. Only two thirds of injured patients from RTI were wearing seat belts, and the case-fatality was high at 2.8% in unbelted and 0.4% in belted respectively. The preventive effects on study outcomes of belted occupants compared to unbelted were higher in drivers than in non-driving passengers.

Seat belt use is the most effective modality for reducing case-fatality and severe injury from RTI, as numerous evidences support the association between seat belt use and reduced occupant case-fatality and health-related cost (7-9). Seat belt use would be lessen the impact from primary collision and prevent second collision of human body to vehicles. Among patients who sustained RTI in this study, any unbelted vehicle occupants, regardless of driver or passenger, had 10 times higher odds for case-fatality compared to those who were belted, 2.5 times higher for intracranial injury, and 2.2 times higher for hospital admission, respectively. Intracranial injury is one of the most fatal anatomical locations from RTI with 9.5% case-fatality rate, and is known to cause substantial disability and sequelae (23).

In terms of seating positions, we observed stronger preventive effects of seat belt on case-fatality in drivers compared to non-driving passengers (OR, 11.71 vs. 5.52, respectively). The risk is higher in unbelted drivers than in unbelted passengers where the crude case-fatality rate was 5.1% in unbelted drivers and 1.3% in unbelted non-driving passengers. On the contrary, when both the driver and front seat passenger were belted, the risk difference of severe injury between drivers and front seat passengers was diminished (18).

Seat belt legislation has been enforced in many countries including Korea where seat belt use has been made compulsory to all vehicle occupants in the vehicle; however, the seat belt use rate has not increased drastically (12-15). Despite the legislative measures to enforce seat belt use, we observed seat belt use in 76.7% among drivers and only 45.6% among non-driving passengers, which may have led to increased mortality and health burden from RTI. Seat belt legislation has been reported to reduce the severity and sequelae of traumatic brain injuries related to RTI, ultimately reducing the overall health burden (24). Primary enforcement seat belt laws mandate seat belt use and are reported to result in higher seat belt use rates and lower RTI case-fatality rates among youth and adults, compared to sec-

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Table 2. Demographic findings and clinical outcomes by driving status

Parameters	Total		Driver		Passenger		*P* value
	No.	%	No.	%	No.	%	
Total	23,698	100	14,465	61.0	9,233	39.0	
Seat belt use							< 0.001
Belted	15,304	64.6	11,091	76.7	4,213	45.6	
Age (yr)							< 0.001
19-29	5,761	24.3	2,934	20.3	2,827	30.6	
30-44	9,047	38.2	6,107	42.2	2,940	31.8	
45-64	7,259	30.6	4,713	32.6	2,546	27.6	
65-	1,631	6.9	711	4.9	920	10.0	
Median (IQR)	39 (30-51)		39 (31-51)		37 (28-52)		
Gender							< 0.001
Female	11,171	47.1	5,061	35.0	6,110	66.2	
Past medical history							
Hypertension	679	2.9	398	2.8	281	3.0	0.189
Diabetes mellitus	338	1.4	225	1.6	113	1.2	0.035
Time of injury							0.036
Daytime (6 am-6 pm)	12,801	54.0	7,892	54.6	4,909	53.2	
Day of injury							< 0.001
Weekend	8,856	37.4	4,886	33.8	3,970	43.0	
Alcohol use	1,489	6.3	832	5.8	657	7.1	< 0.001
EMS use	10,629	44.9	6,330	43.8	4,299	46.6	< 0.001
Time from injury to ED arrival							< 0.001
Minute, median (IQR)	70 (40-251)		80 (42-277)		61 (36-239)		
Initial systolic blood pressure (mmHg)							0.001
0-89	341	1.4	238	1.6	103	1.1	
90-	18,358	77.5	11,135	77.0	7,223	78.2	
Unknown	4,999	21.1	3,092	21.4	1,907	20.7	
Heart rate per minute							0.041
0-59	488	2.1	316	2.2	172	1.9	
60-99	16,330	68.9	9,880	68.3	6,450	69.9	
100-	1,888	8.0	1,184	8.2	704	7.6	
Unknown	4,992	21.1	3,085	21.3	1,907	20.7	
Respiratory rate per minute							0.007
0-9	145	0.6	105	0.7	40	0.4	
10-29	18,461	77.9	11,216	77.5	7,245	78.5	
30-	72	0.3	40	0.3	32	0.3	
Unknown	5,020	21.2	3,104	21.5	1,916	20.8	
Initial mental status							< 0.001
Alert	19,083	80.5	11,579	80.0	7,504	81.3	
Verbal response	177	0.7	130	0.9	47	0.5	
Pain response	157	0.7	113	0.8	44	0.5	
Unresponsive	207	0.9	151	1.0	56	0.6	
Unknown	4,074	17.2	2,492	17.2	1,582	17.1	
ED disposition							< 0.001
Discharge	19,353	81.7	11,677	80.7	7,676	83.1	
Admission to ward	3,130	13.2	1,955	13.5	1,175	12.7	
Admission to ICU	1,028	4.3	220	1.5	338	3.7	
Death in ED	187	0.8	143	1.0	44	0.5	
Clinical outcome							
Case-fatality	297	1.3	220	1.5	77	0.8	< 0.001
Intracranial injury	607	2.6	378	2.6	229	2.5	0.528
Clinically important injury	4,345	18.3	2,788	19.3	1,557	16.9	< 0.001

IQR, interquartile range; EMS, emergency medical services; ED, emergency department; ICU, intensive care unit.

ondary enforcement seat belt laws (25,26). Such results indicate stronger law enforcement is required for effective regulation of seat belt use.

Evidence-based strategies to increase seat belt use should be developed and implemented to increase seat belt use and reduce preventable mortality from RTIs, including extensive public advocacy and campaign, legislation and strong enforcement of related laws, and engineering and developing of new technology such as smart seat belt reminders (27). Monitoring, assurance, and development of legal remedies are necessary to

Table 3. Multivariable logistic regression analysis on study outcomes by seat belt use and driving status

Variables	Total	Outcomes		Unadjusted		Adjusted*	
	No.	No.	%	OR	95% CI	OR	95% CI
Primary outcome: Case-fatality							
Seat belt use							
Belted	15,304	58	0.4	1.00		1.00	
Unbelted	8,394	239	2.8	7.70	5.78-10.28	10.43	7.75-14.04
Driving status							
Driver	9,233	77	0.8	1.00		1.00	
Non-driving passenger	14,465	220	1.5	1.84	1.42-2.38	2.95	2.21-3.94
Secondary outcome: Intracranial injury							
Seat belt use							
Belted	15,304	257	1.7	1.00		1.00	
Unbelted	8,394	350	4.2	2.55	2.16-3.00	2.68	2.25-3.19
Driving status							
Driver	9,233	229	2.5	1.00		1.00	
Non-driving passenger	14,465	378	2.6	1.06	0.89-1.25	1.34	1.11-1.62
Tertiary outcome: Clinically important injury							
Seat belt use							
Belted	15,304	2,216	14.5	1.00		1.00	
Unbelted	8,394	2,129	25.4	2.01	1.88-2.15	2.19	2.04-2.36
Driving status							
Driver	9,233	1,557	16.9	1.00		1.00	
Non-driving passenger	14,465	2,788	19.3	1.18	1.10-1.26	1.41	1.30-1.53

*Adjusted for seat belt use, driving status, age, gender, time of injury, day of injury, alcohol use, and past medical history (hypertension and diabetes). OR, odds ratio; CI, confidence interval.

Table 4. Effects of seat belt use in interaction model with the driving status

Outcomes	Total	Outcome		Adjusted*	
	No.	No.	%	OR	95% CI
Primary outcome: Case-fatality					
Driver					
Seat belt group	11,091	48	0.4	1.00	
No seat belt group	3,374	172	5.1	11.71	8.45-16.22
Non-driving passenger					
Seat belt group	4,213	10	0.2	1.00	
No seat belt group	5,020	67	1.3	5.52	2.83-10.76
Secondary outcome: Intracranial injury					
Driver					
Seat belt group	11,091	192	1.7	1.00	
No seat belt group	3,374	186	5.5	3.05	2.47-3.75
Non-driving passenger					
Seat belt group	4,213	65	1.5	1.00	
No seat belt group	5,020	164	3.3	2.06	1.54-2.76
Tertiary outcome: Clinically important injury					
Driver					
Seat belt group	11,091	1,665	15.0	1.00	
No seat belt group	3,374	1,123	33.3	2.64	2.41-2.90
Non-driving passenger					
Seat belt group	4,213	551	13.1	1.00	
No seat belt group	5,020	1,006	20.0	1.61	1.43-1.81

*Adjusted for seat belt use, driving status, age, gender, time of injury, day of injury, alcohol use, past medical history (hypertension and diabetes), and interaction term (seat belt use × driving status). OR, odds ratio; CI, confidence interval.

enhance the seat belt use for not only the drivers, but all vehicle occupants.

This study has several limitations. First, this is an observational study, not an intervention trial. There may a potential confounding issue that exerted an impact. Second, the seat belt use, which was the main exposure variable, was measured by face-to-face interview by general physicians. This is subject to over- or under-estimation, which can result in bias. Third, we only had information on whether the vehicle occupant was the driver or a non-driving passenger, but could not distinguish

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whether the passenger was seated in front or rear. Injury-related information on the specific seating position, mechanism of collision, the speed at the time of injury, level of blood alcohol level were limited and not fully adjusted.

In conclusion, seat belt use among patients injured from RTI has preventive effects on case-fatality and intracranial injury. The preventive effects were significant both in drivers and passengers. Public health efforts including public campaign, advocacy, and multidisciplinary approaches to increase seat belt use would help reduce health burden from RTIs.

DISCLOSURE

The authors have no potential conflicts of interest to disclose.

AUTHOR CONTRIBUTION

Study concept and design: Kwak BH, Ro YS, Shin SD, Song KJ. Acquisition, analysis, or interpretation of data: Kwak BH, Ro YS, Shin SD. Drafting of the manuscript: Kwak BH, Ro YS, Jang DB. Critical revision of the manuscript for important intellectual content: Ro YS, Shin SD, Song KJ, Kim YJ. Statistical analysis: Kwak BH, Ro YS. Administrative, technical, or material support: Kwak BH, Kim YJ, Jang DB. Study supervision: Shin SD, Song KJ. Manuscript approval: all authors.

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