

THE EFFECT OF ABS AS A PREVENTIVE SAFETY DEVICE: THE RESULT OF STATISTICAL ANALYSIS USING INTEGRATED ROAD TRAFFIC ACCIDENT DATABASE

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ABSTRACT

The object of this study is to evaluate the effect of Antilock Braking System (ABS) as a preventive safety device by statistical analysis of integrated road traffic accident database.

The road traffic accident data including driver and road environment condition and the registered vehicle data including safety device were integrated. The risk of being struck from behind while stopping is not influenced by the driver characteristic of the struck vehicle. So the number of those vehicles/drivers is able to be considered a quasi-induced exposure, and the relative accident rates for some combinations of 7 factors listed later were calculated. Data of 253,035 cars, which were involved in a traffic accident from the year 2002 to 2007, manufactured from the year 1993 to 2000 and driven by a sober, private purpose and seat-belted driver, were analyzed by 7 factors; sex and age of driver, types of collisions, day/night, road surface condition, with/without a passenger and with/without ABS. ABS is expected to reduce the accident rate, especially for some collision types which could be prevented by keeping wheels unlocked.

The results shows; 1) the accident reduction effect of ABS on wet road surface was greater than on dry road surface, and 2) ABS reduced the relative accident rates of a rear-end collision by 1-38% and an single vehicle collision by 10-33%.

There are several discussions about the validity of the quasi-induced exposure method. But the effect of ABS was confirmed by considering the interactive effect with other factors such as age of driver or with/without a passenger. Further studies are required for precise discussion. The developed integrated database and the proposed method are also useful to evaluate other preventive safety devices.

INTRODUCTION

There are a lot of reports about the effect of Antilock Brake System (ABS) (Cumming 2007, Evans 1998, Farmer 1997 and 2001 and VTI 2007). And not only positive effects but also negative effects were reported.

The effect of ABS in real traffic is influenced by several factors, such as driver characteristics, road surface condition, and road traffic environment. Driver characteristics are related to age and sex, safety attitude, trip purpose and others. Therefore it is required to analyze these factors simultaneously or to control the effect of these factors for discussion the effect of ABS.

Institute for Traffic Accident Research and Data Analysis (ITARDA) constructed a database by integrating road traffic accident data and vehicle safety device data in the year 2007.

Information about age and sex of accident driver, trip purpose and other driver characteristics are included in road traffic accident data, and information about equipment of ABS is included in vehicles safety device data. So the effect of ABS in real traffic could be studied using this integrated database.

METHOD

There are a lot of factors that influence the risk of traffic accident. Therefore it is necessary to control an effect of other factors to discuss an effect of ABS. Following factors are controlled in this study; Influence of alcohol, seat belt use, trip purpose, vehicle type and other safety devices.

Influence alcohol: The accident rate is increased under influence of alcohol (Compton 2002).

Therefore "sober" was selected.

Seat belt use: "Belted driver" are analyzed, because

the characteristics of accident caused by an unbelted driver are different from that of belted drivers, and most of drivers are belted nowadays.

Trip purpose: Driver behavior related with accident rate differs in trip purpose. The number of accident drivers on business purpose is smaller than that of private (not business) (Nishida, 2006), and “private” was selected.

Vehicle type: Accident characteristics and a field of view from a driver seat differ in vehicle type. “Car excluding mini-car” was selected because of its popularization.

Other safety device: Cars equipped with brake assist system for ABS, full-time and part-time 4WD, a limited slip differential (LSD), traction control system (TSC) and electronic brake force distribution (EBD) were excluded. Because they should be excluded to discuss the effect of ABS exclusively. (See Table 1)

Table 1.

The number of cars involved in traffic accidents from the year 2002 to 2007 by safety devices (%)

	Equipped			others	total (100%)
	with	without	unclear		
ABS	25.8	1.7	43.9	28.6	4,627,280
Brake assist system for ABS	0.7	1.9	65.0	32.4	
High-mounted stop lamp	19.7	0.0	48.8	31.5	
Full-time 4WD	9.5	55.1	5.6	29.8	
Part-time 4WD	2.5	64.5	2.7	30.3	
LSD	1.3	14.0	53.6	31.1	
TSC	0.7	27.6	36.8	34.9	
Headway warning	0.0	36.8	34.3	28.9	
Traction control system	0.0	3.4	67.7	28.9	
Stability control system	0.0	36.7	34.3	28.9	
EBD	0.7	33.6	36.3	29.4	
Auto headway control system	0.0	37.1	34.0	28.9	
Lane deviation warning	0.0	36.8	34.3	28.9	
Night vision	0.0	37.3	33.8	28.9	
Rear view monitor	0.0	1.8	69.4	28.8	
Blind-corner monitor	0.0	36.3	34.8	28.8	
Tyre pressure warning	0.1	37.3	33.8	28.9	

others: vehicles manufactured before the device register system.

Following factors are analyzed;

Sex and age of driver, day/night, road surface condition and existence of passenger.

Sex of driver: male/female

Age of driver: 18-24 yrs/ 25-44 yrs/ 45-64 yrs/ 65 years and older/all age

Day and night: day/night

Road surface condition: dry/wet*(wet, icy, snowy and unpaved) /all

Passenger: without a passenger/with one passenger
Cases with more than one passenger were excluded, because the effect of multiple passengers was not the

same as single passenger (Engström 2008 and ITARDA 2009).

The period of analysis was from 2002 to 2006.

According to a trial, the number of accidents before 2002 was small for statistical analysis.

The vehicle registered year was from 1993 to 2000.

According to a trial, the number of accident vehicles without ABS after 2001 was small for statistical analysis.

Evaluation index

The relative accident rates were calculated using equation 1 or 2. Rear-end collision with a stopping as the 2nd party (See Table 2) was selected as the control accident. The effect of ABS is discussed with Odds-ratio (Equation 3). And 95% significant limits were calculated using Equation 4 and 5.

$$Rac = \frac{Aac}{Nac} \quad (1).$$

$$Rnc = \frac{Anc}{Nnc} \quad (2).$$

$$E = \frac{Rac}{Rnc} \quad (3).$$

Rac: relative Case accident rate of a vehicle with ABS

Rnc: relative Case accident rate of a vehicle without ABS

Aac: the number of Case accidents in which a vehicle with ABS was involved during the period

Anc: the number of Case accidents in which a vehicle without ABS was involved during the period

Nac: the number of Control accidents in which a vehicle with ABS was involved during the period

Nnc: the number of Control accidents in which a vehicle without ABS was involved during the period

Case accident

d: accident occurred on a dry surface road

w: accident occurred on a wet/icy/snowy road

p: accident caused by a driver with a passenger.
 z: accident caused by a driver without a passenger

E: odds ratio for the effect of ABS in Case accident

95% confidence limits

$$E - dE \text{ (lower)} \quad \text{and} \quad E + dE \text{ (upper)} \quad (4).$$

$$dE = 1.96 * E * \sqrt{\frac{1}{Aac} + \frac{1}{Nac} + \frac{1}{Anc} + \frac{1}{Nnc}} \quad (5).$$

Collision type The effect of ABS is thought to be not the same for all types of collision. Some types of collision are thought to be sensitive to ABS, and others are not. Following major types of collision were selected for this study.

Rear-end/1P: Rear-end collision with a stopping as the first party.

Angle/1P: Angle collision with a vehicle coming from left or right approach/side as the first party

Single-veh: Single-vehicle collision such as collision with object, run-off-the-road, rollover and others (See Table 2)

Table 2.
Collision types and Abbreviations for the study

collision type		level of culpable		
multiple-vehicle	Vehicle - <u>Pedestrian</u>	1/2P		
	Head-on collision	1P	2P	
		1P	2P	
	Rear-end collision with a moving vehicle (rear-end A)	1P	2P	
		1P	2P	
	<u>Rear-end</u> collision with a stopping vehicle (rear-end B)	1P	2P	
		1P	2P	
	<u>Angle</u> collision with a vehicle coming from left or right approach	1P		
	collision with an oncoming vehicle while <u>turning right</u>	1P	2P	
1P		2P		
collision with a vehicle coming from left or right approach while turning	1P	2P		
	1P	2P		
other multiple-vehicle	1P			
	2P			
<u>Single-vehicle</u>	1P			

Level of culpable: 1P is a driver/person having caused the most culpable failure or the least injured among parties concerned when their culpable failure are at the same level.
 2P is a driver/person having caused the lower culpable failure.
Abbreviations are bold and underlined followed by level of culpable(1P/2P).

RESULTS

Relative Accident Rates of Wet Road Surface

ABS can reduce stopping distance by preventing vehicle wheels from locked during hard braking. So the effect of ABS in real traffic depends on how often are vehicles involved in such situation where hard braking is required.

Male driver The number of accident and the relative accident rates by collision type, with/without ABS and with/without a passenger for male drivers are shown in Table 3. Odds-ratios are also presented in Table 3 to discuss the effect of ABS and passenger.

Due to the data size, there are only a few cases that show a significant effect;

Day, rear-end/1P, without a passenger (21% reduction)

Night, rear-end/1P, without a passenger (38%)

Night, single-veh/1P, without a passenger (33%)

Night, rear-end/1P, with a passenger (55%)

Night, all types/1P, without a passenger (24%)

There are more cases at night than in daytime. The reason might be that more hard braking are required at night because of poor visual environment.

The effect of passenger is greater than that of ABS.

Because most of human accident causes are thought to be visual cognition errors.

A passenger may assist a driver mostly in collecting visual information. On the other hand, ABS reducing a stopping distance may help a driver mostly in operating a vehicle. Therefore it is reasonable that the effect of passenger is greater than that of ABS.

The effect of passenger was discussed later.

Female driver Table 4 shows the result of female driver similar way to Table 3.

There are some groups that show a significant effect statistically, but the data size was small.

ABS was developed to reduce a stopping distance by preventing the lockup of vehicle wheels during hard braking, and the effect of ABS is thought to be higher on wet road surface where wheels may be locked easily. The results shown in Table 3 and 4 were consistent with this assumption.

Table 3.
Relative accident rates by collision type,
with/without ABS and with/without a passenger
(all age, male drivers and wet* road surface)

~ Day ~

collision type	without a passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
Rear-end/IP	2914	241	386	28
Angle/IP	2418	178	439	26
Case: Single-veh/IP	277	20	130	4
Pedestrian	592	35	77	7
All types/IP	9019	693	1546	91
Control: Rear-end/2P	2151	140	1159	59
Relative accident rates	Raz	Rnz	Rap	Rnp
Rear-end/IP	1.35	1.72	0.33	0.47
Angle/IP	1.12	1.27	0.38	0.44
Single-veh/IP	0.13	0.14	0.11	0.07
Pedestrian	0.28	0.25	0.07	0.12
All types/IP	4.19	4.95	1.33	1.54
Odds-ratio	effect of ABS			
	without a passenger		with passenger	
	Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Rear-end/IP	0.79	0.62 - 0.96	0.70	0.38 - 1.03
Angle/IP	0.88	0.68 - 1.09	0.86	0.45 - 1.27
Single-veh/IP	0.90	0.46 - 1.34	1.65	0.00 - 3.36
Pedestrian	1.10	0.68 - 1.52	0.56	0.10 - 1.02
All types/IP	0.85	0.69 - 1.01	0.86	0.57 - 1.16
	effect of a passenger			
	with ABS		without ABS	
	Rap/Raz	(95% C.I.)	Rnp/Rnz	(95% C.I.)
Rear-end/IP	0.25	0.21 - 0.28	0.28	0.14 - 0.41
Angle/IP	0.34	0.30 - 0.38	0.35	0.17 - 0.52
Single-veh/IP	0.87	0.68 - 1.06	0.47	0.00 - 1.00
Pedestrian	0.24	0.18 - 0.30	0.47	0.06 - 0.89
All types/IP	0.32	0.29 - 0.35	0.31	0.19 - 0.43

~ night-time ~

collision type	without a passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
Rear-end/IP	1821	164	198	20
Angle/IP	1226	66	230	11
Case: Single-veh/IP	292	24	105	4
Pedestrian	765	48	100	2
All types/IP	6110	448	1019	63
Control: Rear-end/2P	1389	77	679	31
Relative accident rates	Raz	Rnz	Rap	Rnp
Rear-end/IP	1.31	2.13	0.29	0.65
Angle/IP	0.88	0.86	0.34	0.35
Single-veh/IP	0.21	0.31	0.15	0.13
Pedestrian	0.55	0.62	0.15	0.06
All types/IP	4.40	5.82	1.50	2.03
Odds-ratio	effect of ABS			
	without a passenger		with passenger	
	Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Rear-end/IP	0.62	0.44 - 0.79	0.45	0.19 - 0.72
Angle/IP	1.03	0.68 - 1.38	0.95	0.28 - 1.63
Single-veh/IP	0.67	0.35 - 0.99	1.20	0.00 - 2.47
Pedestrian	0.88	0.56 - 1.21	2.28	0.00 - 5.58
All types/IP	0.76	0.57 - 0.94	0.74	0.41 - 1.06
	effect of a passenger			
	with ABS		without ABS	
	Rap/Raz	(95% C.I.)	Rnp/Rnz	(95% C.I.)
Rear-end/IP	0.22	0.18 - 0.26	0.30	0.11 - 0.49
Angle/IP	0.38	0.32 - 0.45	0.41	0.10 - 0.73
Single-veh/IP	0.74	0.56 - 0.91	0.41	0.00 - 0.88
Pedestrian	0.27	0.21 - 0.33	0.10	0.00 - 0.26
All types/IP	0.34	0.30 - 0.38	0.35	0.18 - 0.52

wet* : not dry (wet, icy, snowy etc.). 95% C.I.: 95% confidence limits
Number in bold : significantly effective

Table 4.
Relative accident rates by collision type,
with/without ABS and with/without a passenger
(all age female drivers and wet* road surface)

~ Day ~

collision type	without a passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
Rear-end/IP	1315	86	185	10
Angle/IP	1520	75	263	16
Case: Single-veh/IP	119	1	37	4
Pedestrian	354	13	43	0
All types/IP	4673	251	766	47
Control: Rear-end/2P	1493	75	554	23
Relative accident rates	Raz	Rnz	Rap	Rnp
Rear-end/IP	0.88	1.15	0.33	0.43
Angle/IP	1.02	1.00	0.47	0.70
Single-veh/IP	0.08	0.01	0.07	0.17
Pedestrian	0.24	0.17	0.08	0.00
All types/IP	3.13	3.35	1.38	2.04
Odds-ratio	effect of ABS			
	without a passenger		with passenger	
	Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Rear-end/IP	0.77	0.52 - 1.01	0.77	0.18 - 1.35
Angle/IP	1.02	0.68 - 1.35	0.68	0.24 - 1.13
Single-veh/IP	5.98	0.00 - 17.83	0.38	0.00 - 0.81
Pedestrian	1.37	0.55 - 2.19	-	-
All types/IP	0.94	0.69 - 1.18	0.68	0.33 - 1.02
	effect of a passenger			
	with ABS		without ABS	
	Rap/Raz	(95% C.I.)	Rnp/Rnz	(95% C.I.)
Rear-end/IP	0.38	0.31 - 0.45	0.38	0.07 - 0.68
Angle/IP	0.47	0.39 - 0.54	0.70	0.20 - 1.19
Single-veh/IP	0.84	0.51 - 1.15	13.04	0.00 - 42.27
Pedestrian	0.33	0.22 - 0.43	-	-
All types/IP	0.44	0.38 - 0.49	0.61	0.27 - 0.95

~ Night ~

collision type	without a passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
Rear-end/IP	634	40	78	5
Angle/IP	525	25	103	6
Case: Single-veh/IP	92	16	32	1
Pedestrian	310	17	43	2
All types/IP	2253	132	404	21
Control: Rear-end/2P	627	38	301	15
Relative accident rates	Raz	Rnz	Rap	Rnp
Rear-end/IP	1.01	1.05	0.26	0.33
Angle/IP	0.84	0.66	0.34	0.40
Single-veh/IP	0.15	0.42	0.11	0.07
Pedestrian	0.49	0.45	0.14	0.13
All types/IP	3.59	3.47	1.34	1.40
Odds-ratio	effect of ABS			
	without a passenger		with passenger	
	Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Rear-end/IP	0.96	0.52 - 1.40	0.78	0.00 - 1.59
Angle/IP	1.27	0.61 - 1.93	0.86	0.02 - 1.69
Single-veh/IP	0.35	0.13 - 0.57	1.59	0.00 - 4.87
Pedestrian	1.11	0.46 - 1.75	1.07	0.00 - 2.69
All types/IP	1.03	0.65 - 1.42	0.96	0.31 - 1.61
	effect of a passenger			
	with ABS		without ABS	
	Rap/Raz	(95% C.I.)	Rnp/Rnz	(95% C.I.)
Rear-end/IP	0.26	0.19 - 0.33	0.32	0.00 - 0.67
Angle/IP	0.41	0.31 - 0.51	0.61	0.00 - 1.26
Single-veh/IP	0.72	0.42 - 1.03	0.16	0.00 - 0.49
Pedestrian	0.29	0.19 - 0.39	0.30	0.00 - 0.77
All types/IP	0.37	0.31 - 0.44	0.40	0.10 - 0.71

wet* : not dry (wet, icy, snowy etc.). 95% C.I.: 95% confidence limits
Number in bold : significantly effective

Table 5.

**Relative accident rates by collision type,
with/without ABS and with/without a passenger
(all age male drivers and all road surfaces)**

~ Day ~

collision type	without a passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
Rear-end/1P	22308	1509	2506	163
Angle/1P	19083	1146	2966	171
Case: Single-veh/1P	975	81	465	28
Pedestrian	4784	257	597	29
All types/1P	70195	4424	10325	596
Control: Rear-end/2P	14823	879	7599	373
Relative accident rates	Raz	Rnz	Rap	Rnp
Rear-end/1P	1.50	1.72	0.33	0.44
Angle/1P	1.29	1.30	0.39	0.46
Single-veh/1P	0.07	0.09	0.06	0.08
Pedestrian	0.32	0.29	0.08	0.08
All types/1P	4.74	5.03	1.36	1.60
Odds-ratio	effect of ABS			
	without a passenger		with passenger	
	Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Rear-end/1P	0.88	0.80 - 0.95	0.75	0.61 - 0.90
Angle/1P	0.99	0.90 - 1.08	0.85	0.69 - 1.01
Single-veh/1P	0.71	0.54 - 0.88	0.82	0.49 - 1.14
Pedestrian	1.10	0.95 - 1.26	1.01	0.62 - 1.40
All types/1P	0.94	0.87 - 1.01	0.85	0.74 - 0.96
	effect of a passenger			
	with ABS		without ABS	
	Rap/Raz	(95% C.I.)	Rnp/Rnz	(95% C.I.)
Rear-end/1P	0.22	0.21 - 0.23	0.25	0.20 - 0.31
Angle/1P	0.30	0.29 - 0.32	0.35	0.28 - 0.42
Single-veh/1P	0.93	0.82 - 1.04	0.81	0.45 - 1.18
Pedestrian	0.24	0.22 - 0.27	0.27	0.16 - 0.37
All types/1P	0.29	0.28 - 0.30	0.32	0.27 - 0.36

~ Night ~

collision type	without a passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
Rear-end/1P	10188	700	1061	75
Angle/1P	6438	379	1105	73
Case: Single-veh/1P	975	80	346	29
Pedestrian	3144	176	390	22
All types/1P	31851	2049	4823	314
Control: Rear-end/2P	6884	424	3350	191
Relative accident rates	Raz	Rnz	Rap	Rnp
Rear-end/1P	1.48	1.65	0.32	0.39
Angle/1P	0.94	0.89	0.33	0.38
Single-veh/1P	0.14	0.19	0.10	0.15
Pedestrian	0.46	0.42	0.12	0.12
All types/1P	4.63	4.83	1.44	1.64
Odds-ratio	effect of ABS			
	without a passenger		with passenger	
	Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Rear-end/1P	0.90	0.78 - 1.01	0.81	0.58 - 1.03
Angle/1P	1.05	0.90 - 1.20	0.86	0.62 - 1.10
Single-veh/1P	0.75	0.56 - 0.94	0.68	0.40 - 0.96
Pedestrian	1.10	0.90 - 1.30	1.01	0.55 - 1.47
All types/1P	0.96	0.85 - 1.06	0.88	0.71 - 1.04
	effect of a passenger			
	with ABS		without ABS	
	Rap/Raz	(95% C.I.)	Rnp/Rnz	(95% C.I.)
Rear-end/1P	0.21	0.20 - 0.23	0.24	0.17 - 0.31
Angle/1P	0.35	0.33 - 0.38	0.43	0.30 - 0.56
Single-veh/1P	0.73	0.63 - 0.82	0.80	0.44 - 1.17
Pedestrian	0.25	0.23 - 0.28	0.28	0.15 - 0.41
All types/1P	0.31	0.30 - 0.33	0.34	0.27 - 0.41

wet* : not dry (wet, icy, snowy etc.), 95% C.I.: 95% confidence limits
Number in bold : significantly effective

Table 6.

**Relative accident rates by collision type,
with/without ABS and with/without a passenger
(all age female drivers and all road surfaces)**

~ Day ~

collision type	without a passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
Rear-end/1P	9710	464	1329	56
Angle/1P	11531	499	1833	80
Case: Single-veh/1P	521	25	174	16
Pedestrian	2975	108	390	11
All types/1P	35486	1564	5550	238
Control: Rear-end/2P	9599	378	3723	146
Relative accident rates	Raz	Rnz	Rap	Rnp
Rear-end/1P	1.01	1.23	0.36	0.38
Angle/1P	1.20	1.32	0.49	0.55
Single-veh/1P	0.05	0.07	0.05	0.11
Pedestrian	0.31	0.29	0.10	0.08
All types/1P	3.70	4.14	1.49	1.63
Odds-ratio	effect of ABS			
	without a passenger		with passenger	
	Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Rear-end/1P	0.82	0.71 - 0.94	0.93	0.64 - 1.22
Angle/1P	0.91	0.79 - 1.03	0.90	0.65 - 1.15
Single-veh/1P	0.82	0.48 - 1.16	0.43	0.20 - 0.66
Pedestrian	1.08	0.85 - 1.32	1.39	0.53 - 2.25
All types/1P	0.89	0.79 - 1.00	0.91	0.72 - 1.11
	effect of a passenger			
	with ABS		without ABS	
	Rap/Raz	(95% C.I.)	Rnp/Rnz	(95% C.I.)
Rear-end/1P	0.35	0.33 - 0.38	0.31	0.21 - 0.42
Angle/1P	0.41	0.38 - 0.44	0.42	0.29 - 0.54
Single-veh/1P	0.86	0.71 - 1.01	1.66	0.57 - 2.74
Pedestrian	0.34	0.30 - 0.38	0.26	0.09 - 0.43
All types/1P	0.40	0.38 - 0.42	0.39	0.30 - 0.49

~ Night ~

collision type	without a passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
Rear-end/1P	2914	241	386	28
Angle/1P	2418	178	439	26
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Control: Rear-end/2P	2151	140	1159	59
Relative accident rates	Raz	Rnz	Rap	Rnp
Rear-end/1P	1.35	1.72	0.33	0.47
Angle/1P	1.12	1.27	0.38	0.44
Single-veh/1P	0.13	0.14	0.11	0.07
Pedestrian	0.28	0.25	0.07	0.12
All types/1P	4.19	4.95	1.33	1.54
Odds-ratio	effect of ABS			
	without a passenger		with passenger	
	Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Rear-end/1P	0.79	0.62 - 0.96	0.70	0.38 - 1.03
Angle/1P	0.88	0.68 - 1.09	0.86	0.45 - 1.27
Single-veh/1P	0.90	0.46 - 1.34	1.65	0.00 - 3.36
Pedestrian	1.10	0.68 - 1.52	0.56	0.10 - 1.02
All types/1P	0.85	0.69 - 1.01	0.86	0.57 - 1.16
	effect of a passenger			
	with ABS		without ABS	
	Rap/Raz	(95% C.I.)	Rnp/Rnz	(95% C.I.)
Rear-end/1P	0.25	0.21 - 0.28	0.28	0.14 - 0.41
Angle/1P	0.34	0.30 - 0.38	0.35	0.17 - 0.52
Single-veh/1P	0.87	0.68 - 1.06	0.47	0.00 - 1.00
Pedestrian	0.24	0.18 - 0.30	0.47	0.06 - 0.89
All types/1P	0.32	0.29 - 0.35	0.31	0.19 - 0.43

wet* : not dry (wet, icy, snowy etc.), 95% C.I.: 95% confidence limits
Number in bold : significantly effective

Table 7.
Relative accident rate by age group, with/without
ABS and road surface condition
(Rear-end/IP, male, without a passenger)

~ Day ~

age	wet* road surface		dry road surface	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	586	61	3231	298
25-44yrs	1129	80	7323	401
Case 45-64yrs	824	66	5957	365
65yrs-	375	34	2883	203
All age	2914	241	19394	1268
Control (Rear-end/2P)				
18-24yrs	215	21	1027	72
25-44yrs	895	46	5242	272
45-64yrs	807	55	4916	284
65yrs-	234	18	1485	111
All age	2151	140	12672	739
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	2.73	2.90	3.15	4.14
25-44yrs	1.26	1.74	1.40	1.47
45-64yrs	1.02	1.20	1.21	1.29
65yrs-	1.60	1.89	1.94	1.83
All age	1.35	1.72	1.53	1.72
<Odds-ratio>				
	effect of ABS			
	wet* road surface		dry road surface	
	Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
18-24yrs	0.94	0.45 - 1.43	0.76	0.56 - 0.96
25-44yrs	0.73	0.45 - 1.00	0.95	0.80 - 1.10
45-64yrs	0.85	0.54 - 1.17	0.94	0.79 - 1.09
65yrs-	0.85	0.34 - 1.35	1.06	0.81 - 1.32
All age	0.79	0.62 - 0.96	0.89	0.81 - 0.98

~ Night ~

age	wet* road surface		dry road surface	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	500	50	2171	159
25-44yrs	805	62	3754	217
Case 45-64yrs	415	39	1923	121
65yrs-	100	13	518	38
All age	1821	164	8367	536
Control (Rear-end/2P)				
18-24yrs	215	13	827	62
25-44yrs	726	33	2834	167
45-64yrs	395	28	1595	99
65yrs-	53	3	239	19
All age	1389	77	5495	347
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	2.33	3.85	2.63	2.56
25-44yrs	1.11	1.88	1.32	1.30
45-64yrs	1.05	1.39	1.21	1.22
65yrs-	1.89	4.33	2.17	2.00
All age	1.31	2.13	1.52	1.54
<Odds-ratio>				
	effect of ABS			
	wet* road surface		dry road surface	
	Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
18-24yrs	0.60	0.22 - 0.99	1.02	0.71 - 1.34
25-44yrs	0.59	0.33 - 0.85	1.02	0.81 - 1.23
45-64yrs	0.75	0.37 - 1.13	0.99	0.72 - 1.26
65yrs-	0.44	-0.13 - 1.00	1.08	0.46 - 1.70
All age	0.62	0.44 - 0.79	0.99	0.85 - 1.12

95% C.I. : 95% confidence limits

Numbers in bold : significantly effective

Table 8.
Relative accident rate by age group, with/without
ABS and road surface condition
(Rear-end/IP, female, without a passenger)

~ Day ~

age	wet* road surface		dry road surface	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	183	15	990	77
25-44yrs	637	35	3980	135
Case 45-64yrs	447	32	3015	140
65yrs-	48	4	410	26
All age	1315	86	8395	378
Control (Rear-end/2P)				
18-24yrs	93	7	486	37
25-44yrs	735	35	4038	109
45-64yrs	612	32	3252	144
65yrs-	53	1	330	13
All age	1493	75	8106	303
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	1.97	2.14	2.04	2.08
25-44yrs	0.87	1.00	0.99	1.24
45-64yrs	0.73	1.00	0.93	0.97
65yrs-	0.91	4.00	1.24	2.00
All age	0.88	1.15	1.04	1.25
<Odds-ratio>				
	effect of ABS			
	wet* road surface		dry road surface	
	Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
18-24yrs	0.92	0.06 - 1.77	0.98	0.58 - 1.38
25-44yrs	0.87	0.45 - 1.28	0.80	0.59 - 1.00
45-64yrs	0.73	0.36 - 1.10	0.95	0.73 - 1.18
65yrs-	0.23	-0.28 - 0.73	0.62	0.20 - 1.04
All age	0.77	0.52 - 1.01	0.83	0.70 - 0.96

~ Night ~

age	wet* road surface		dry road surface	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	150	14	579	52
25-44yrs	309	10	1289	51
Case 45-64yrs	159	15	892	36
65yrs-	16	1	83	2
All age	634	40	2843	141
Control (Rear-end/2P)				
18-24yrs	71	6	259	22
25-44yrs	328	18	1286	61
45-64yrs	214	14	832	41
65yrs-	14	0	56	1
All age	627	38	2433	125
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	2.11	2.33	2.24	2.36
25-44yrs	0.94	0.56	1.00	0.84
45-64yrs	0.74	1.07	1.07	0.88
65yrs-	1.14	#DIV/0!	1.48	2.00
All age	1.01	1.05	1.17	1.13
<Odds-ratio>				
	effect of ABS			
	wet* road surface		dry road surface	
	Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
18-24yrs	0.91	0.00 - 1.81	0.95	0.45 - 1.44
25-44yrs	1.70	0.36 - 3.03	1.20	0.74 - 1.65
45-64yrs	0.69	0.17 - 1.22	1.22	0.66 - 1.78
65yrs-	-	-	0.74	-1.06 - 2.54
All age	0.96	0.52 - 1.40	1.04	0.78 - 1.29

95% C.I. : 95% confidence limits

Numbers in bold : significantly effective

Table 9.
Relative accident rate by age group, with/without
ABS and road surface condition
(Single-vehicle/1P, male, without a passenger)

age	wet* road surface		dry road surface	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	59	6	124	17
25-44yrs	112	4	180	14
Case 45-64yrs	69	6	187	19
65yrs-	37	4	207	11
All age	277	20	698	61
Control (Rear-end/2P)				
18-24yrs	215	21	1027	72
25-44yrs	895	46	5242	272
45-64yrs	807	55	4916	284
65yrs-	234	18	1485	111
All age	2151	140	12672	739
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	0.27	0.29	0.12	0.24
25-44yrs	0.13	0.09	0.03	0.05
45-64yrs	0.09	0.11	0.04	0.07
65yrs-	0.16	0.22	0.14	0.10
All age	0.13	0.14	0.06	0.08
<Odds-ratio>				
effect of ABS				
	wet* road surface		dry road surface	
	Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
18-24yrs	0.96	0.05 - 1.87	0.51	0.22 - 0.80
25-44yrs	1.44	-0.06 - 2.94	0.67	0.30 - 1.04
45-64yrs	0.78	0.10 - 1.47	0.57	0.29 - 0.85
65yrs-	0.71	-0.10 - 1.52	1.41	0.51 - 2.30
All age	0.90	0.46 - 1.34	0.67	0.49 - 0.85

~ Night ~

age	wet* road surface		dry road surface	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	73	5	219	18
25-44yrs	143	11	306	22
Case 45-64yrs	54	7	127	15
65yrs-	22	1	31	1
All age	292	24	683	56
Control (Rear-end/2P)				
18-24yrs	215	13	827	62
25-44yrs	726	33	2834	167
45-64yrs	395	28	1595	99
65yrs-	53	3	239	19
All age	1389	77	5495	347
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	0.34	0.38	0.26	0.29
25-44yrs	0.20	0.33	0.11	0.13
45-64yrs	0.14	0.25	0.08	0.15
65yrs-	0.42	0.33	0.13	0.05
All age	0.21	0.31	0.12	0.16
<Odds-ratio>				
effect of ABS				
	wet* road surface		dry road surface	
	Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
18-24yrs	0.88	-0.06 - 1.82	0.91	0.41 - 1.41
25-44yrs	0.59	0.17 - 1.01	0.82	0.44 - 1.20
45-64yrs	0.55	0.07 - 1.03	0.53	0.22 - 0.83
65yrs-	1.25	-1.64 - 4.13	2.46	-2.58 - 7.51
All age	0.67	0.35 - 1.00	0.77	0.54 - 1.00

95% C.I. : 95% confidence limits

Numbers in bold : significantly effective

Table 10.
Relative accident rate by age group, with/without
ABS and road surface condition
(Angle/1P, male, without a passenger)

age	wet* road surface		dry road surface	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	273	31	1663	154
25-44yrs	776	50	5044	240
Case 45-64yrs	841	58	6198	342
65yrs-	528	39	3760	231
All age	2418	178	16665	968
Control (Rear-end/2P)				
18-24yrs	215	21	1027	72
25-44yrs	895	46	5242	272
45-64yrs	807	55	4916	284
65yrs-	234	18	1485	111
All age	2151	140	12672	739
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	1.27	1.48	1.62	2.14
25-44yrs	0.87	1.09	0.96	0.88
45-64yrs	1.04	1.05	1.26	1.20
65yrs-	2.26	2.17	2.53	2.08
All age	1.12	1.27	1.32	1.31
<Odds-ratio>				
effect of ABS				
	wet* road surface		dry road surface	
	Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
18-24yrs	0.86	0.36 - 1.36	0.76	0.54 - 0.98
25-44yrs	0.80	0.47 - 1.13	1.09	0.90 - 1.28
45-64yrs	0.99	0.61 - 1.37	1.05	0.88 - 1.22
65yrs-	1.04	0.44 - 1.64	1.22	0.93 - 1.50
All age	0.88	0.68 - 1.09	1.00	0.91 - 1.10

~ Night ~

age	wet* road surface		dry road surface	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	250	21	1070	89
25-44yrs	483	24	2135	115
Case 45-64yrs	391	18	1510	81
65yrs-	102	3	497	28
All age	1226	66	5212	313
Control (Rear-end/2P)				
18-24yrs	215	13	827	62
25-44yrs	726	33	2834	167
45-64yrs	395	28	1595	99
65yrs-	53	3	239	19
All age	1389	77	5495	347
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	1.16	1.62	1.29	1.44
25-44yrs	0.67	0.73	0.75	0.69
45-64yrs	0.99	0.64	0.95	0.82
65yrs-	1.92	1.00	2.08	1.47
All age	0.88	0.86	0.95	0.90
<Odds-ratio>				
effect of ABS				
	wet* road surface		dry road surface	
	Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
18-24yrs	0.72	0.20 - 1.23	0.90	0.60 - 1.20
25-44yrs	0.91	0.42 - 1.41	1.09	0.83 - 1.36
45-64yrs	1.54	0.60 - 2.48	1.16	0.81 - 1.51
65yrs-	1.92	-1.22 - 5.07	1.41	0.56 - 2.26
All age	1.03	0.68 - 1.38	1.05	0.89 - 1.22

95% C.I. : 95% confidence limits

Numbers in bold : significantly effective

Table 11.
Relative accident rates by age group, with/without ABS and with/without a passenger (Rear-end/IP, male, wet* road surface)

~ Day ~

age	with out passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	586	61	92	14
25-44yrs	1129	80	122	3
Case 45-64yrs	824	66	102	9
65yrs-	375	34	70	2
All age	2914	241	386	28
Control (Rear-end/2P)				
18-24yrs	215	21	123	12
25-44yrs	895	46	416	19
45-64yrs	807	55	443	23
65yrs-	234	18	177	5
All age	2151	140	1159	59
Relative accident rates				
	Ran	Rnn	Rap	Rnp
18-24yrs	2.73	2.90	0.75	1.17
25-44yrs	1.26	1.74	0.29	0.16
45-64yrs	1.02	1.20	0.23	0.39
65yrs-	1.60	1.89	0.40	0.40
All age	1.35	1.72	0.33	0.47
<Odds-ratio>				
effect of ABS				
	with out passenger		with a passenger	
	Ran/Rnn	(95% C.I.)	Rap/Rnp	(95% C.I.)
18-24yrs	0.94	0.45 - 1.43	0.64	0.12 - 1.16
25-44yrs	0.73	0.45 - 1.00	1.86	-0.44 - 4.15
45-64yrs	0.85	0.54 - 1.17	0.59	0.12 - 1.06
65yrs-	0.85	0.34 - 1.35	0.99	-0.66 - 2.63
All age	0.79	0.62 - 0.96	0.70	0.38 - 1.03

~ Night ~

age	with out passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	500	50	89	11
25-44yrs	805	62	66	1
Case 45-64yrs	415	39	28	5
65yrs-	100	13	15	3
All age	1821	164	198	20
Control (Rear-end/2P)				
18-24yrs	215	13	173	9
25-44yrs	726	33	313	9
45-64yrs	395	28	162	10
65yrs-	53	3	31	3
All age	1389	77	679	31
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	2.33	3.85	0.51	1.22
25-44yrs	1.11	1.88	0.21	0.11
45-64yrs	1.05	1.39	0.17	0.50
65yrs-	1.89	4.33	0.48	1.00
All age	1.31	2.13	0.29	0.65
<Odds-ratio>				
effect of ABS				
	with out passenger		with a passenger	
	Ran/Rnn	(95% C.I.)	Rap/Rnp	(95% C.I.)
18-24yrs	0.60	0.22 - 0.99	0.42	0.03 - 0.81
25-44yrs	0.59	0.33 - 0.85	1.90	-2.06 - 5.85
45-64yrs	0.75	0.37 - 1.13	0.35	-0.05 - 0.74
65yrs-	0.44	-0.13 - 1.00	0.48	-0.35 - 1.31
All age	0.62	0.44 - 0.79	0.45	0.19 - 0.72

95% C.I. : 95% confidence limits

Numbers in bold : significantly effective

Table 12.
Relative accident rates by age group, with/without ABS and with/without a passenger (Rear-end/IP, male, dry road surface)

~ Day ~

age	with out passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	3231	298	497	36
25-44yrs	7323	401	623	36
Case 45-64yrs	5957	365	563	32
65yrs-	2883	203	437	31
All age	19394	1268	2120	135
Control (Rear-end/2P)				
18-24yrs	1027	72	663	50
25-44yrs	5242	272	2294	98
45-64yrs	4916	284	2430	108
65yrs-	1485	111	1053	58
All age	12672	739	6440	314
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	3.15	4.14	0.75	0.72
25-44yrs	1.40	1.47	0.27	0.37
45-64yrs	1.21	1.29	0.23	0.30
65yrs-	1.94	1.83	0.42	0.53
All age	1.53	1.72	0.33	0.43
<Odds-ratio>				
effect of ABS				
	with out passenger		with a passenger	
	Ran/Rnn	(95% C.I.)	Rap/Rnp	(95% C.I.)
18-24yrs	0.76	0.56 - 0.96	1.04	0.58 - 1.50
25-44yrs	0.95	0.80 - 1.10	0.74	0.45 - 1.03
45-64yrs	0.94	0.79 - 1.09	0.78	0.47 - 1.10
65yrs-	1.06	0.81 - 1.32	0.78	0.43 - 1.13
All age	0.89	0.81 - 0.98	0.77	0.61 - 0.92

~ Night ~

age	with out passenger		with a passenger	
	with ABS	without ABS	with ABS	without ABS
Number of accidents				
18-24yrs	2171	159	376	22
25-44yrs	3754	217	299	19
Case 45-64yrs	1923	121	130	3
65yrs-	518	38	58	11
All age	8367	536	863	55
Control (Rear-end/2P)				
18-24yrs	827	62	654	54
25-44yrs	2834	167	1246	57
45-64yrs	1595	99	606	41
65yrs-	239	19	165	8
All age	5495	347	2671	160
Relative accident rates				
	Raw	Rnw	Rad	Rnd
18-24yrs	2.63	2.56	0.57	0.41
25-44yrs	1.32	1.30	0.24	0.33
45-64yrs	1.21	1.22	0.21	0.07
65yrs-	2.17	2.00	0.35	1.38
All age	1.52	1.54	0.32	0.34
<Odds-ratio>				
effect of ABS				
	with out passenger		with a passenger	
	Ran/Rnn	(95% C.I.)	Rap/Rnp	(95% C.I.)
18-24yrs	1.02	0.71 - 1.34	1.41	0.69 - 2.13
25-44yrs	1.02	0.81 - 1.23	0.72	0.34 - 1.10
45-64yrs	0.99	0.72 - 1.26	2.93	-0.55 - 6.41
65yrs-	1.08	0.46 - 1.70	0.26	0.01 - 0.50
All age	0.99	0.85 - 1.12	0.94	0.64 - 1.24

95% C.I. : 95% confidence limits

Numbers in bold : significantly effective

Relative Accident Rates of All Road Surface

The effect of ABS on wet* surface was confirmed. But wheels might be locked on not only wet surface but also dry surface, because a driver may make a hard braking on dry surface.

Table 5 and 6 show the results of all road surface condition similar way to Table 3 and 4. The groups that show significant effects are as follows;

Male

Day, rear-end/IP, with|without a passenger (12%, 25% reduction)

Day, single-vehicle/IP, without a passenger (29%)

Day, all types of collision, with a passenger (15%)

Night, single-vehicle, with|without a passenger (25%, 32%)

Female

Day, rear-end/IP, without a passenger (18%)

Day, single-vehicle, with a passenger (57%)

Night, rear-end/IP, without a passenger (21%)

Due to the small data size, the effect of ABS was not shown for some potential groups. But ABS may reduce the risk of rear-end/IP and single-vehicle/IP on all surface conditions even if there are differences between reduction levels.

The differences between the reduction levels might be explained with the road use and driving characteristics.

Relative Accident Rates by Road Surface Condition and Driver Age

The road use and driving characteristics are related to sex and age of driver.

Table 7 and 8 show the numbers of accidents and the relative accident rates by age group, road surface condition and with/without ABS. Odds-ratios are also presented in these tables to discuss the effect of ABS by road surface condition.

The data size of female drivers on wet* surface is so small that female drivers on wet* were not discussed even if there is a significant effect statistically.

The significant effects are shown in following groups;

Day,

Male, 18-24yrs, dry (24% reduction)

Male, all age, dry|wet* (21%, 11%)

Female, all age, dry (17%)

Night

Male, 18-24yrs|25-44yrs, wet* (40%, 41%)

These results of younger drivers are consistent with an assumption that the effect of ABS is great for drivers those who might make a hard braking frequently.

Relative Accident Rates by collision type and driver age

The effect of ABS was confirmed for rear-end/IP and single-vehicle/IP for all age group. For further discussion about type of collision, the number of accidents and the relative accident rates by age group, road surface condition and with/without ABS for single-vehicle and angle collision were calculated.

Female drivers were not analyzed because of small data size. Odds-ratios are also calculated.

Single-vehicle Table 9 shows the result of single-vehicle collision. The significant effects are shown in following groups;

Day, 18-24yrs|44-64yrs, dry (49%, 43% reduction)

Night, 45-64yrs, dry (47%)

The difference between the effects of ABS is thought to reflect the road use and driving characteristics for each age group.

Angle collision Table 10 shows the result of angle collision. There is a significant effect for one group. However it is better to conclude that there is no effect of ABS for angle-collision as shown in Table 3, 4, 5 and 6 considering odds-ratios of others.

Relative Accident Rates by With/without a Passenger and driver age

The significant effects of passenger were shown in Table 3, 4, 5 and 6. And Table 11 and 12 were shown for further discussion about the effect of ABS considering the existence of a passenger.

The significant effects of ABS were shown in following groups;

Wet*

Day, 18-24|25-44|45-64|65yrs- , without a passenger (6%, 27%, 15%, 15% and 21% reduction)

Night, 18-24|25-44yrs, without a passenger (40%, 41%)

Dry

Day, 18-24yrs, without a passenger (24%)

Day, all age, with|without a passenger (11%, 23%)

Table 13.

The effect of ABS by road surface condition, sex of driver and day/night (Rear-end/IP, all age, without a passenger)

		wet* road surface		dry road surface	
		Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
Male	day	0.79	0.62 - 0.96	0.89	0.81 - 0.98
	night	0.62	0.44 - 0.79	0.99	0.85 - 1.12
Female	day	0.77	0.52 - 1.01	0.83	0.70 - 0.96
	night	0.96	0.52 - 1.40	1.04	0.78 - 1.29

Table 14.

The effect of ABS by road surface condition, collision type and day/night (All age, male, without a passenger)

		wet* road surface		dry road surface	
		Raw/Rnw	(95% C.I.)	Rad/Rnd	(95% C.I.)
Rear-end/IP	day	0.79	0.62 - 0.96	0.89	0.81 - 0.98
	night	0.62	0.44 - 0.79	0.99	0.85 - 1.12
Single-veh/IP	day	0.90	0.46 - 1.34	0.67	0.49 - 0.85
	night	0.67	0.35 - 1.00	0.77	0.54 - 1.00
Angle/IP	day	0.88	0.68 - 1.09	1.00	0.91 - 1.10
	night	1.03	0.68 - 1.38	1.05	0.89 - 1.22

Table 15.

The effect of ABS by with/without a passenger, road surface condition, and day/night (Rear-end/IP, all age, male)

		with out passenger		with a passenger	
		Raz/Rnz	(95% C.I.)	Rap/Rnp	(95% C.I.)
Wet *	day	0.79	0.62 - 0.96	0.70	0.38 - 1.03
	night	0.62	0.44 - 0.79	0.45	0.19 - 0.72
Dry	day	0.89	0.81 - 0.98	0.77	0.61 - 0.92
	night	0.99	0.85 - 1.12	0.94	0.64 - 1.24

DISCUSSION

Age and sex

There are several ideas about the relation between the effect of ABS, age and frequency of hard braking.

A young driver may make a reckless driving easily so that he may experience much hard braking.

An old driver might reduce his cognition ability especially visual, so he may make much cognition errors and hard braking.

But there is no remarkable relation between the effect of ABS and age (See Table 7 and 8).

It is necessary to study about road use and driving characteristics of younger and older drivers for further discussion.

Sex, day/night and road surface condition

The data of odds-ratios for all age of Table 7 and 8 are arranged (See Table 13). There are some groups without significant effects. However it is clear that the effect of ABS is greater on wet* surface than dry surface without regard to sex and day/night.

For male drivers, the effect of ABS is the greatest on wet* surface at night. But for female drivers, there is not such a tendency. A female driver may change her driving behavior according to road traffic condition or may make it a rule not drive at night.

Collision type

The data of odds-ratios for all age of Table 7, 9 and 10 are arranged (See Table 14). There are some groups without significant effects.

At night the effect of ABS is greater on wet* surface (33%) than dry surface (23%) for single-vehicle/IP, but there is not a significant difference between wet* and dry surface for angle collision/IP.

Rear-end/IP and single-vehicle/IP can be reduced by improving braking performance but angle collision can not be improved as much as rear-end/IP or single-vehicle/IP.

Because the main cause of angle collision or vehicle-pedestrian collision is cognition-error or inadequate driving behavior and an improvement of braking performance rarely reduce the risk of these collisions.

Passenger

The data of odds-ratios for all age of Table 11 and 12 are arranged (See Table 15). There is an effect of ABS without regard to existence of passenger or road surface condition, and the reduction effect is greater for with a passenger (wet*-day 30%, wet*-night 55%, dry-day 23%, dry-night 6% reduction) than without a passenger (21%, 38%, 11%, 1%).

On wet* surface the effect at night (without a

passenger 38%, with a passenger 55%) is greater than in daytime (21%, 30%), but on dry surface the effect at night-time (without a passenger 1%, with a passenger 6%) is smaller than in daytime (11%, 23%).

Control data: Quasi-induced exposure

In this study the odds-ratios of day and night, male and female and wet* and dry were not compared with directly. Because these factors are related to road use and driving characteristics, which influence the rate of accident, including rear-end collision.

The results show that there is an effect of ABS to reduce rear-end collisions. So the number of rear-end/2P is expected to be decreasing according to increase of cars with ABS. Therefore conditions of these factors were controlled to give the same influence to each group in this study.

The author made several calculations using the number of vehicle-pedestrian collision or angle collision instead of rear-end/2P. But the results were not reasonable, because the number of these collisions does not satisfy the condition of control data; the control data should be not influenced by driving characteristics of concerned drivers.

Improving the effect of ABS

The effect of ABS with a passenger is greater than that without a passenger.

This result shows the mechanism of supporting a driver that ABS is helping a driver in operation and a passenger is helping him in cognition. And the effect of ABS may be improved with other safety device that assists a driver in cognition.

Accident experience

Accident experience might influence driving characteristics. There is not useful information about the relation between the effect of ABS and accident experience (Cummings 2007), but another integrated database of ITARDA (Nishida 2008) may be useful for discussion of this topic.

CONCLUSIONS

Using the integrated database, the effect of ABS was analyzed considering following factors; road surface condition, sex and age of driver, collision type, day/night and existence of passenger.

The results show;

- 1) ABS has a reduction effect of rear-end collision (1-38% reduction) and single-vehicle collision (10-33%),
- 2) the level of reduction differs in sex and age of driver, day/night and road surface condition,
- 3) the effect of ABS with a passenger is greater than that without a passenger,
- 4) the effect of ABS is not clear for some driver groups, but this result is explained by considering road use and driving characteristics of these groups.

The information are useful to improve the effect of ABS not only the viewpoint of from education but also engineering.

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