CORRELATION BETWEEN JNCAP PEDESTRIAN HEAD PROTECTION PERFORMANCE TESTS AND REAL-WORLD ACCIDENTS

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ABSTRACT

The pedestrian head protection performance test was introduced to the Japan New Car Assessment Program (JNCAP) in 2003. Fifty-four car models were tested in 2005. The tests rated total pedestrian head protection performance of cars into levels 1 through 5. Also, the Japanese government began regulating pedestrian head protection for passenger cars in 2005. It is expected that cars are becoming less aggressive in pedestrian accidents.
In such situations, we are interested in the effectiveness of the pedestrian head protection tests introduced in JNCAP.
We will use Japanese national accident data between 2001 and 2005. The pedestrian fatality/severe-injury rate (the number of pedestrians killed or severely injured divided by the total number of pedestrians involved in the accidents) is an index of crash safety for pedestrians. The logistic regression method is applied to adjust for confounding factors (gender of pedestrian, age of pedestrian, guilt of pedestrian, day or night accident and travel speed of the car).
As a result of the study, we saw a correlation between the fatality/severe-injury rate and pedestrian head protection performance levels (1 to 4) in test results, suggesting that passenger cars with better test results protect pedestrians from severe injury in real-world accidents. Also, we observed that fatality/severe-injury rate of car models without pedestrian protection design are higher than that of car models with pedestrian head protection design, suggesting that passenger cars with pedestrian protection design are safer than those without pedestrian protection design in case of pedestrian accidents.

INTRODUCTION

In the early 1990's, fatalities in car accidents were increasing every year, and car-to-car and single car accidents, which constituted to about 47% of all fatal accidents, were the most frequent [1]. The JNCAP tests and the government regulations were introduced in Japan from the middle of the 1990's to reduce the number of fatalities of car drivers or passengers. In Japan, the second most frequent accident type is car-to-pedestrian accident, which constitutes about 25% of all fatal accidents. Reducing fatalities of pedestrians is therefore important in Japan. To this end, JNCAP initiated pedestrian head protection performance tests in 2003, and the government introduced regulations in 2005. It is now expected that car manufacturers will build cars more friendly to pedestrians. In such situations, it is important to investigate if JNCAP pedestrian tests conducted in the laboratory using head impactors are related to real-world accidents.
In this paper, we examine the effectiveness of the pedestrian head protection tests introduced in JNCAP. To see this effectiveness, we set two objectives in our study. One objective is to determine whether JNCAP pedestrian head protection ratings relate to pedestrian safety in real-world accidents. We call this the "Correlation study." The other objective is to determine whether introducing the JNCAP tests had any real effect on pedestrian accidents with regard to injury severity. We call this the "Pedestrian test introduction effect study."
It must be acknowledged that pedestrian protection regulations were introduced only two years after the JNCAP pedestrian head protection tests began, so the regulations' effects are more or less included in our study.

METHOD

Accident Data

The study uses Japanese national accident data compiled by the Institute for Traffic Accident Research and Data Analysis (ITARDA). The accident data we deal with in this paper are car-to-pedestrian accidents, in which pedestrians were hit by passenger cars tested by JNCAP [2]. We focused on accidents where the front of the car hit the pedestrian in order to match the form of the pedestrian test in JNCAP. Also, pedestrians who were not injured are excluded from the analysis. As we have two objectives in our study, we established two accident databases. These are explained below.

Correlation Study - The car models tested in the JNCAP pedestrian test are presented in Table 1. They are classified into five pedestrian head protection performance evaluation levels.

Table 1.
Cars in JNCAP pedestrian tests

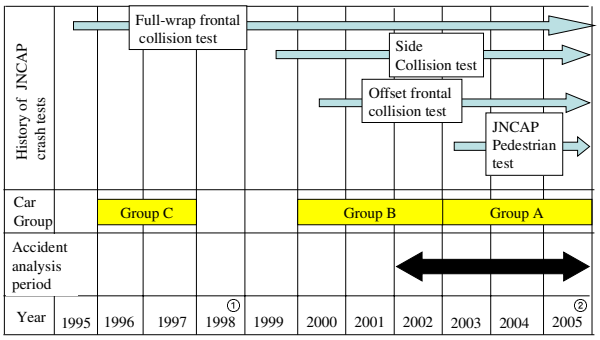
Level	Manufacturer	Model	Model code	Category
1	Suzuki	ALTO Lapin	HE21S	Mini-sized cars
	Suzuki	Jimny	JB23W	Mini-sized cars
	Mazda	RX-8	SE3P	Passenger Cars B
	Toyota	HARRIER	ACU30W	Passenger Cars C
2	Suzuki	wagonR	MH21S	Mini-sized cars
	Honda	LIFE	JB5	Mini-sized cars
	Subaru	R2	RC1	Mini-sized cars
	Subaru	SAMBAR	TV1	Mini-sized cars
	Daihatsu	HIJET	S320V	Mini-sized cars
	Mitsubishi	COLT	Z25A	Passenger Cars A
	Toyota	RAUM	NCZ20	Passenger Cars A
	Toyota	PRIUS	NHW20	Passenger Cars A
	Nissan	WINGROAD	Y12	Passenger Cars A
	Subaru	LEGACY Touring Wagon	BP5	Passenger Cars B
	Nissan	TEANA	J31	Passenger Cars C
	Honda	INSPIRE	UC1	Passenger Cars C
	Toyota	CROWN	GRS182	Passenger Cars C
	Toyota	Lexus IS	GSE20	Passenger Cars C
	Mitsubishi	GRANDIS	NA4W	1BOX & Minivans
	Nissan	PRESAGE	TU31	1BOX & Minivans
	Toyota	Probox VAN	NCP51V	Commercial cars
	Nissan	AD VAN	VFY11	Commercial cars
	Nissan	VANETTE VAN	SK82VN	Commercial cars
3	Daihatsu	MIRA	L250S	Mini-sized cars
	Suzuki	ALTO	HA24S	Mini-sized cars
	Daihatsu	Tanto	L350S	Mini-sized cars
	Suzuki	EVERY	DA64V	Mini-sized cars
	Toyota	WiLL CYPHA	NCP70	Passenger Cars A
	Toyota	PASSO	KGC10	Passenger Cars A
	Suzuki	SWIFT	ZC11S	Passenger Cars A
	Toyota	Porte	NNP10	Passenger Cars A
	Mazda	VERISA	DC5W	Passenger Cars A
	Nissan	TIIDA	C11	Passenger Cars A
	Toyota	Belta	KSP92	Passenger Cars A
	Nissan	NOTE	E11	Passenger Cars A
	Mazda	AXELA	BKEP	Passenger Cars B
	Honda	Edix	BE1	Passenger Cars B
	Volkswagen	Golf	1KAXW	Passenger Cars B
	Honda	CIVIC	FD1	Passenger Cars B
	Nissan	FUGA	Y50	Passenger Cars C
	Toyota	WISH	ZNE10G	1BOX & Minivans
	Honda	ODYSSEY	RB1	1BOX & Minivans
	Toyota	SIENTA	NCP81G	1BOX & Minivans
	Nissan	LAFESTA	B30	1BOX & Minivans
	Honda	ELYSION	RR1	1BOX & Minivans
	Mazda	PREMACY	CREW	1BOX & Minivans
	Nissan	SERENA	C25	1BOX & Minivans
4	Daihatsu	mira GINO	L650S	Mini-sized cars
	Toyota	Vitz	KSP90	Passenger Cars A
	Toyota	Ractis	NCP100	Passenger Cars A
	Honda	AIRWAVE	GJ1	Passenger Cars A
	Suzuki	ESCUDO	TD54W	Passenger Cars B
	Toyota	MARK X	GRX120	Passenger Cars C
	Toyota	Isis	ANM10W	1BOX & Minivans
	Honda	STEP WGN	RG1	1BOX & Minivans
5	Toyota	RAV4	ACA31W	Passenger Cars C

On this basis, there were 4,710 pedestrians in accidents, of whom 780 sustained fatal or severe injuries.

Pedestrian Test Introduction Effect Study - As in the correlation study, we focused on car-to-pedestrian accidents, in which pedestrians were hit by passenger cars tested by JNCAP. JNCAP primarily selects cars for tests among the top-selling car models in the market. We made three groups of car models classified by the test year in JNCAP. Group A contains car models in Table 1 excluding mini-sized cars. We define group A as car models with pedestrian head protection design (ppd). Group B contains car models tested between 2000 and 2002 in JNCAP (Table 2). We define group B as some car models with p.p.d. Group C contains car models tested between 1996 and 1997 in JNCAP (Table 3) and which do not have ppd.

We defined the ppd by JNCAP test year for the following reasons (Figure 1). The first car model with ppd seemed to be released in 1998 by Honda, so we define car models in Group C (without ppd) as those tested in JNCAP before 1998. We assume that car models tested in JNCAP pedestrian tests have some degree of ppd, so we define them as Group A (with ppd). For Group A and Group C, which include cars tested between 1998 and 2002, some cars may have ppd but some may not. JNCAP began offset frontal crash testing in 2000, and many models were re-tested at that time. We therefore selected test years 2000 to 2002 for Group B (with some ppd).

Mini-sized cars are not included in the accident data in all groups because there were no mini-sized cars in Group C. During that time, JNCAP did not test mini-sized cars.



① First car model designed to protect pedestrian's head released into the market
② Pedestrian head protection regulation started

Figure 1. Definition of car groups by JNCAP test years

Table 2.
Cars in JNCAP tests (Group B)

Manufacturer	Model	Model code	Category
Toyota	Vitz	SCP10	Passenger Cars A
Nissan	CUBE	AZ10	Passenger Cars A
Toyota	FUN CARGO	NCP20	Passenger Cars A
Toyota	COROLLA	NZE121	Passenger Cars A
Nissan	SUNNY	FB15	Passenger Cars A
Honda	CIVIC	EU1	Passenger Cars A
Nissan	WINGROAD	WFY11	Passenger Cars A
Toyota	PRIUS	NHW11	Passenger Cars A
Honda	Fit	GD1	Passenger Cars A
Toyota	bB	NCP31	Passenger Cars A
Subaru	IMPREZA Sports Wagon	GG2	Passenger Cars A
Nissan	MARCH	AK12	Passenger Cars A
Toyota	ist	NCP60	Passenger Cars A
Nissan	CUBE	BZ11	Passenger Cars A
Mazda	DEMIO	DY3W	Passenger Cars A
Toyota	MARK Ⅱ	GX110	Passenger Cars B
Subaru	LEGACY B4	BE5	Passenger Cars B
Nissan	BLUEBIRD SYLPHY	QG10	Passenger Cars B
Mitsubishi	LANCER SEDIA WAGON	CS5W	Passenger Cars B
Toyota	RAV4	ACA21W	Passenger Cars B
Nissan	PRIMERA WAGON	WTP12	Passenger Cars B
Nissan	X-TRAIL	NT30	Passenger Cars B
Honda	CR-V	RD5	Passenger Cars B
Subaru	LEGACY Touring Wagon	BH5	Passenger Cars B
Toyota	PREMIO	ZZT240	Passenger Cars B
Toyota	CALDINA	AZT241W	Passenger Cars B
Subaru	FORESTER	SG5	Passenger Cars B
Toyota	CROWN	JZS171	Passenger Cars C
Nissan	CEDRIC	HY34	Passenger Cars C
Nissan	SKYLINE	V35	Passenger Cars C
Nissan	STAGEA	M35	Passenger Cars C
Toyota	WINDOM	MCV30	Passenger Cars C
Toyota	BREVIS	JCG10	Passenger Cars C
Mazda	Atenza	GG3S	Passenger Cars C
Honda	ACCORD	CL9	Passenger Cars C
Mitsubishi	Dion	CR9W	1BOX & Minivans
Nissan	SERENA	PC24	1BOX & Minivans
Honda	Odyssey	RA6	1BOX & Minivans
Toyota	ESTIMA	ACR30W	1BOX & Minivans
Mazda	MPV	LW5W	1BOX & Minivans
Toyota	COROLLA SPACIO	NZE121N	1BOX & Minivans
Honda	STREAM	RN1	1BOX & Minivans
Toyota	IPSUM	ACM21W	1BOX & Minivans
Honda	STEPWGN	RF3	1BOX & Minivans
Honda	MOBILIO	GB1	1BOX & Minivans
Toyota	NOAH	AZR60G	1BOX & Minivans
Nissan	LIBERTY	RM12	1BOX & Minivans
Toyota	ALPHARD	ANH10W	1BOX & Minivans

Table 3.
Cars in JNCAP tests (Group C)

Manufacturer	Model	Model code	Category
Toyota	CORSA	EL51	Passenger Cars A
Nissan	PULSAR	FN15	Passenger Cars A
Toyota	CORONA	AT211	Passenger Cars B
Volkswagen	GOLF	1HADY	Passenger Cars B
Subaru	LEGACY TOURING WAGON	BG5	Passenger Cars B
Nissan	CEFIRO	A32	Passenger Cars B
Honda	CR-V	RD1	Passenger Cars B
Mitsubishi	DIAMANTE	F31A	Passenger Cars C
Honda	ODYSSEY	RA1	1BOX & Minivans
Mitsubishi	DELICA SPACE GEAR	PE8W	1BOX & Minivans
Honda	LOGO	GA3	Passenger Cars A
Nissan	MARCH	K11	Passenger Cars A
Toyota	STARLET	EP91	Passenger Cars A
Mazda	DEMIO	DW3W	Passenger Cars A
Nissan	SUNNY	FB14	Passenger Cars A
Nissan	BLUEBIRD	EU14	Passenger Cars B
Honda	ORTHIA	EL2	Passenger Cars B
Toyota	MARK Ⅱ	GX100	Passenger Cars B
Daimler Benz	Mercedes-Benz	202020	Passenger Cars B
Mitsubishi	LEGNUM	EA1W	Passenger Cars B
Nissan	LAUREL	HC35	Passenger Cars B
Honda	STEPWGN	RF1	1BOX & Minivans
Toyota	CROWN	JZS151	Passenger Cars C
Nissan	CEDRIC	HY33	Passenger Cars C

Logistic Regression Analysis

The logistic model we built is described by equation (1). P is the fatality/severe-injury rate (the number of killed or severely injured pedestrians divided by the total number of pedestrians involved in the accidents). The definition of fatality/severe-injury is that a person died or required medical treatment for a month (30 days or more) as a result of the accident.

$$Ln\frac{P}{1-P} = \beta_0 + \beta_1 \bullet \mathrm{X}_1 + \bullet\bullet\bullet + \beta_k \bullet \mathrm{X}_k \tag{1}$$

The six variables listed below are considered as confounders and are adjusted by logistic regression. Gender, age, and guilt are pedestrian factors, travel speed is a vehicle factor, and day or night is an accident factor. All of the variables are categorical. We categorized age in two ways, rough and detailed.

- Pedestrian's gender (male, female)
- Pedestrian's age (0-6, 7-64, 65+) or age (0-4, 5-9, 10-18, 19-39, 40-49, 50-59, 60-69, 70+)
- Pedestrian's guilt (guilty, not guilty)
- Vehicle travel speed (0km/h to 50km/h, more than 50km/h)
- day or night (day, night)

These variables were introduced into the logistic model by a stepwise selection procedure in statistical software SAS (ver.9) considering the first order of interaction.
After the models were made, we estimated the adjusted odds ratio to compare with the non-adjusted odds ratio estimated from the result without logistic regression adjustment. At the end of the study, we estimated adjusted fatality/severe-injury rate as shown in equation (2) for the correlation study and equation (3) for the pedestrian test introduction effect study in order to interpret the results more easily.

$$P_i = \frac{1}{1+e^{-(\beta_{01}+\beta_i \bullet (\text{Pedestrian head protection evaluation})_i)}} \tag{2}$$

$$P_j = \frac{1}{1+e^{-(\beta_{02}+\beta_j \bullet (\text{Car group})_j)}} \tag{3}$$

Analysis Patterns

When conducting logistic regressions, we made several analyses to detect the effect of categorization of age (rough or detailed) and limitation of travel speed (all travel speeds or eliminating high travel speed). If results change drastically, we must discuss the reasons.

For correlation analysis, we conducted four patterns of analyses (Table 4). The concept of Analysis A-1 is that it is a simple model in that there are three or fewer categories for each variable. Analysis A-2 has a more detailed categorization of age than Analysis A-1 as there are eight age categories. Analysis A-3 has the same categorizations as Analysis A-2, but we focused on accidents with vehicle travel speeds of less than 40km/h because the pedestrian impact speed with the car is thought to be 40km/h in the pedestrian test. Speeds exceeding this in real accidents may be beyond the scope of experiment. However, the travel speed is not so accurate, so we expanded the travel speed to less than 50km/h in Analysis A-4.

Table 4.
Analysis patterns for correlation study

Analysis No.	Number of accidents	Extra conditons on accident data	Variable				
			Day/night	Travel speed	Guilt	Gender	Age
A-1	4,710		1. Day 2. Night	1. 0km/h to less than 50km/h 2. More than 50km/h	1. Guilty 2. Not guilty	1. Male 2. Female	1. 0 to 6 2. 7 to 64 3. 65+
A-2	4,710		↑	↑	↑	↑	1. 0 to 4 2. 5 to 9 3. 10 to 18 4. 19 to 39 5. 40 to 49 6. 50 to 59 7. 60 to 69 8. 70+
A-3	4,391	Travel speed is 0km/h to less than 40km/h					↑
A-4	4,602	Travel speed is 0km/h to less than 50km/h					

We conducted two analyses for the pedestrian test introduction effect study (Table 5). Analysis B-1 has rough age categories, whereas Analysis B-2 has detailed age categories.

Table 5.
Analysis patterns for study of investigating the effect of introducing pedestrian test in JNCAP

Analysis No.	Number of accidents	Variable				
		Day/night	Travel speed	Guilt	Gender	Age
B-1	29,187	1. Day 2. Night	1. 0km/h to less than 50km/h 2. More than 50km/h	1. Guilty 2. Not guilty	1. Male 2. Female	1. 0 to 6 2. 7 to 64 3. 65+
B-2	↑	↑				1. 0 to 4 2. 5 to 9 3. 10 to 18 4. 19 to 39 5. 40 to 49 6. 50 to 59 7. 60 to 69 8. 70+

RESULTS AND DISCUSSION

Correlation Study

<u>Correlation between Non-adjusted Fatality/severe-injury Rate and Pedestrian Head Protection Performance Evaluation</u> - Figure 2 plots the fatality/severe-injury rate versus pedestrian head protection performance evaluation. The data of Figure 2 are presented in Table 6. The fatality/severe-injury rate of level one is higher than those of levels 2 and 3, and there is no difference between level 2 and 3. The 95% confidence interval of the fatality/severe-injury rate in level 4 is so wide that it is not significantly different from other levels.

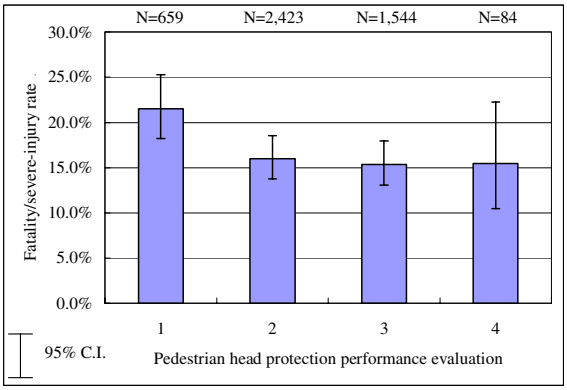


Figure 2. Fatality/severe-injury (non-adjusted) rate versus pedestrian head protection performance evaluation

Table 6.
Fatality/severe-injury rate (non-adjusted) versus pedestrian head protection performance evaluation

Pedestrian head protection performance evaluation	Injury severity			Total	Fatality/ severe-injury rate	95 %Confidence int.	
	Fatal	Severe	Minor			Lower	Upper
1	32	110	517	659	21.5%	18.25%	25.27%
2	43	345	2,035	2,423	16.0%	13.76%	18.56%
3	28	209	1,307	1,544	15.3%	13.06%	17.96%
4	2	11	71	84	15.5%	10.47%	22.28%
Total	105	675	3,930	4,710	16.6%	-	-

Remark: There was no accident for evaluation level 5 car model.

The fatality/severe-injury rate (non-adjusted) will be converted to a non-adjusted odds ratio (Table 7) in order to compare the results of logistic regression analyses. Level 1 of the pedestrian head protection performance evaluation is a reference of the odds ratio.

Table 7.
Non-adjusted odds ratio

Pedestrian head protection performance evaluation	Odds ratio	95% Confidence int.	
		Lower	Upper
1	1.000	-	-
2	0.743	0.560	0.860
3	0.712	0.524	0.832
4	0.718	0.359	1.238

Correlation between Adjusted Odds Ratio and Pedestrian Head Protection Performance Evaluation (Analysis A) - Table 8 presents the regression coefficients of the logistic regression model. Only gender was not selected in the stepwise variable selection procedures. The adjusted odds ratio is estimated from the regression coefficients of the pedestrian head protection evaluation and presented in Table 9.

Table 8.
Regression coefficients of analysis (Analysis A-1)

Variable	Category	Regression coefficient	Standard error
Intercept		-0.3422	-
day/night	day	-0.5500	0.1421
	night	0.5500	0.1421
speed	0km/h - 50km/h	-1.0517	0.1194
	more than 50km/h	1.0517	0.1194
guilt	guilty	0.2300	0.0913
	not guilty	-0.2300	0.0913
age	0-6	-0.2600	0.1023
	7-64	-0.4654	0.0667
	65+	0.7254	0.0684
daynight X speedest	day X (0km/h - 50km/h)	0.2671	0.1196
	night X (0km/h - 50km/h)	0.2671	0.1196
daynight X guilt	day X guilty	0.0018	0.0906
	night X not guilty	0.0018	0.0906
pedestrian head protection evaluation	Level1	0.2841	0.1146
	Level2	0.0132	0.0988
	Level3	-0.0791	0.1039
	Level4	-0.2182	0.2509

AIC=3859.007, Adjusted R^2=0.1345

Table 9.
Adjusted odds ratio (Analysis A-1)

Pedestrian head protection performance evaluation	Odds ratio	95% Confidence int.	
		Lower	Upper
1	1.000	-	-
2	0.763	0.607	0.958
3	0.695	0.544	0.899
4	0.605	0.307	1.193

Table 10 lists the regression coefficients of the logistic regression model in Analysis A-2. The adjusted odds ratio is estimated from the regression coefficient of the pedestrian head protection evaluation and presented in Table 11.

Table 10.
Regression coefficients of analysis (Analysis A-2)

Variable	Category	Regression coefficient	Standard error
Intercept		-0.4344	-
day/night	day	-0.2934	0.0447
	night	0.2934	0.0447
speed	0km/h - 50km/h	-1.1677	0.1144
	more than 50km/h	1.1677	0.1144
guilt	guilty	0.2727	0.1038
	not guilty	-0.2727	0.1038
age	0-4	0.2472	0.2811
	5-9	-0.3714	0.1837
	10-18	-1.0522	0.3584
	19-39	-0.8035	0.2892
	40-49	0.3556	0.2688
	50-59	0.2537	0.2618
	60-69	0.0762	0.3113
	70+	1.2943	0.2061
guilt X age	guilty X 0-4	0.4394	0.2805
	guilty X 5-9	-0.1964	0.1821
	guilty X 10-18	-0.5825	0.3586
	guilty X 19-39	-0.0924	0.2887
	guilty X 40-49	0.7075	0.2689
	guilty X 50-59	-0.0219	0.2611
	guilty X 60-69	-0.4331	0.3112
	not guilty X 5-9	0.1964	0.1821
	not guilty X 10-18	0.5825	0.3586
	not guilty X 19-39	0.0924	0.2887
	not guilty X 40-49	-0.7075	0.2689
	not guilty X 50-59	0.0219	0.2611
	not guilty X 60-69	0.4331	0.3112
	not guilty X 70+	-0.1793	0.2059
pedestrian head protection evaluation	Level1	0.2580	0.1151
	Level2	-0.0129	0.0991
	Level3	-0.0897	0.1043
	Level4	-0.1554	0.2507

AIC=3795.672, Adjusted R^2=0.1617

Table 11.
Adjusted odds ratio (Analysis A-2)

Pedestrian head protection performance evaluation	Odds ratio	95% Confidence int.	
		Lower	Upper
1	1.000	-	-
2	0.763	0.605	0.961
3	0.706	0.551	0.905
4	0.661	0.336	1.304

Table 11 lists the regression coefficients of the logistic regression model in Analysis A-3. The adjusted odds ratio is estimated from the regression coefficients of the pedestrian head protection evaluation and presented in Table 13.

Table 12.
Regression coefficients of analysis (Analysis A-3)

Variable	Category	Regression coefficient	Standard error
Intercept		-1.9906	-
day/night	day	-0.2141	0.0489
	night	0.2141	0.0489
age	0-4	0.0104	0.2314
	5-9	-0.1559	0.1246
	10-18	-0.6064	0.1999
	19-39	-0.8040	0.1410
	40-49	-0.2076	0.1609
	50-59	0.2440	0.1221
	60-69	0.4102	0.1134
	70+	1.1093	0.0890
pedestrian head protection evaluation	Level1	0.1999	0.1281
	Level2	0.0402	0.1086
	Level3	-0.0524	0.1140
	Level4	-0.1876	0.2762

AIC=3306.635, Adjusted R^2=0.0944

Table 13.
Adjusted odds ratio (Analysis A-3)

Pedestrian head protection performance evaluation	Odds ratio	95%Confidence int.	
		Lower	Upper
1	1.000	-	-
2	0.852	0.652	1.103
3	0.777	0.590	1.023
4	0.679	0.321	1.436

Table 14 lists the regression coefficients of the logistic regression model in Analysis A-4. The adjusted odds ratio is estimated from the regression coefficients of the pedestrian head protection evaluation and presented in Table 15.

The odds ratios of Analysis A-1 to A-4 results are presented in Figure 3 for comparison. Level 1 of the pedestrian head protection performance evaluation is a reference of the odds ratio. There is almost no difference between A-1 and A-2, which means that using rough and detailed age categorizations does not affect the result. In Analysis A-3, the odds ratio increased but still the odds ratio tends to decrease with the pedestrian head protection performance evaluation levels. In A-3, we focused only on accidents in which the travel speed is less than 40km/h. However, the trend became weaker when excluded the high-speed accidents. In Analysis A-4, we focused on accidents in which the travel speed was less than 50km/h, which is 10 km/h faster than in A-3. The result of A-4 is similar to the result of A-2. In summary, analyses A-1 through A-4 indicate that the odds ratio tends to decrease with the pedestrian head protection performance evaluation level. There thus seems to be a correlation between the odds ratio and the pedestrian head protection performance evaluation.

Table 14.
Regression coefficients of analysis (Analysis A-4)

Variable	Category	Regression coefficient	Standard error
Intercept		-1.6662	-
day/night	day	-0.2727	0.0453
	night	0.2727	0.0453
guilt	guilty	0.2510	0.0916
	not guilty	-0.2510	0.0916
age	0-4	-0.0198	0.2209
	5-9	-0.2172	0.1207
	10-18	-0.7197	0.1956
	19-39	-0.7396	0.1305
	40-49	-0.2059	0.1513
	50-59	0.2572	0.1153
	60-69	0.4960	0.1061
	70+	1.1489	0.0848
pedestrian head protection evaluation	Level1	0.3026	0.1195
	Level2	0.0335	0.1034
	Level3	-0.0676	0.1087
	Level4	-0.2686	0.2647

AIC=0.0641, Adjusted R^2=0.1114

Table 15.
Adjusted odds ratio (Analysis A-4)

Pedestrian head protection performance	Odds ratio	95%Confidence int.	
		Lower	Upper
1	1.000	-	-
2	0.764	0.604	0.966
3	0.691	0.536	0.899
4	0.565	0.276	1.155

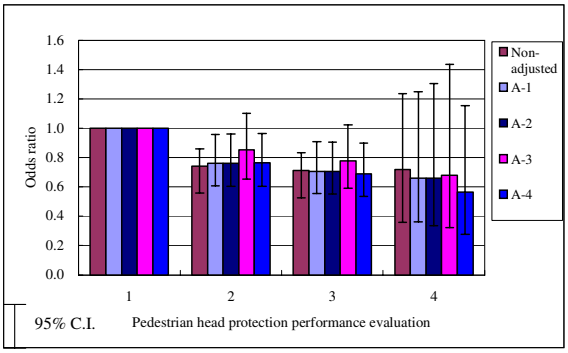


Figure 3. Comparison of non-adjusted and adjusted odds ratios

<u>Adjusted Fatality/severe-injury Rate versus Pedestrian Head Protection Performance Evaluation (Final)</u> - The odds ratio to fatality/severe-injury rate for Analysis A-1 is presented in Figure 4 and Table 16 to indicate the correlation it represents. We consider that Analysis A-1 is a representative result because the odds ratio tended to decrease with the pedestrian head protection performance evaluation level for all analyses (A-1 to A-4).

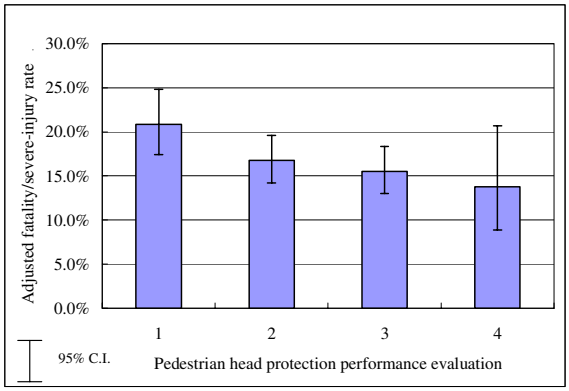


Figure 4. Adjusted Fatality/severe-injury rate (Analysis A-1) versus pedestrian head protection performance evaluation

Table 16.
Adjusted fatality/severe-injury rate (Analysis A-1) versus pedestrian head protection performance evaluation

Pedestrian head protection performance	Adjusted fatality/ severe-injury rate	95%Confidence int.	
		Lower	Upper
1	20.87%	17.40	24.82
2	16.74%	14.22	19.62
3	15.50%	13.01	18.36
4	13.76%	8.89	20.69

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Non-adjusted Fatality/severe-injury Rate by Car Groups with or without PPD - Figure 5 plots the fatality/severe-injury rate versus car group with or without ppd. The data of Figure 5 are presented in Table 17. The fatality/severe-injury rate of group A is lower than that of group B, and the fatality/severe-injury rate of group B is lower than that of group C. Car Group C has no pedestrian protection design. Some cars in group B have pedestrian protection designs, and all cars in group A have pedestrian protection designs. With regard to the non-adjusted fatality/severe-injury rate, we can see that a car group with more pedestrian protection design is less aggressive to pedestrians.

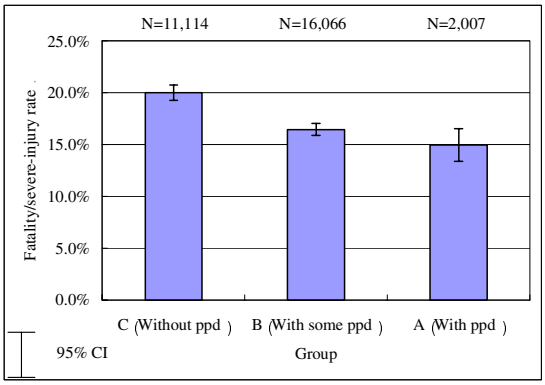

Figure 5. Fatality/severe-injury rate (non-adjusted) versus groups of with or without ppd

Table 17.
Fatality/severe-injury rate (non-adjusted) by group

Group		C	B	A
Pedestrian head prodection design		Without	With some	With
JNCAP test year		1996 - 1997	2000 - 2002	2003 - 2005
Injury severerity	Fatal	338	382	36
	Severe	1,884	2,260	264
	Minor	8,892	13,424	1707
Total		11,114	16,066	2,007
Fatality/severe -injury rate		19.99%	16.44%	14.95%
95% C.I.	Upper	20.74%	17.02%	16.51%
	Lower	19.25%	15.87%	13.39%

The Fatality/severe-injury rate (non-adjusted) will be converted to a non-adjusted odds ratio (Table 18) in order to compare the results of logistic regression analyses. Group C is the reference of the odds ratio.

Table 18.
Non-Adjusted odds ratio

Group	Odds ratio	95%Confidence	
		Lower	Upper
C (Without ppd)	1.000	-	-
B(With some ppd)	0.788	0.740	0.838
A (With ppd)	0.703	0.617	0.802

Adjusted Odds Ratio by Car Group with or without PPD (Analysis B) - Table 19 lists the regression coefficients of the logistic regression model in Analysis B-1. The adjusted odds ratio is estimated from the regression coefficients of groups A to C and presented in Table 20.

Table 19.
Regression coefficients of Analysis (Analysis B-1)

Variable	Category	Regression coefficient	Standard error
Intercept		-0.5289	-
day/night	day	-0.3301	0.0414
	night	0.3301	0.0414
speed	0km/h - 50km/h	-0.8354	0.0915
	more than 50km/h	0.8354	0.0915
guilt	guilty	0.0270	0.0603
	not guilty	-0.0270	0.0603
age	0-6	-0.4223	0.1598
	7-64	-0.2007	0.0886
	65+	0.6229	0.0924
day/night X guilt	day X first	-0.1115	0.0340
	night X first	-0.1115	0.0340
speed X guilt	(0km/h - 50km/h) X first	0.2832	0.0613
	(more than 50km/h) X first	0.2832	0.0613
daynight X age	day X 0-5	0.1818	0.0592
	day X 6-64	-0.0216	0.0338
	night X 6-64	0.0216	0.0338
	night X 65+	0.1602	0.0348
speed X age	(stopping - 50km/h) X 0-5	0.0100	0.1544
	(stopping - 50km/h) X 6-64	-0.1693	0.0863
	(- 60km/h or more) X 6-64	0.1693	0.0863
	(- 60km/h or more) X 65+	-0.1593	0.0902
group	A	-0.1303	0.0453
	B	-0.0171	0.0279
	C	0.1474	0.0287

AIC=24700.418, Adjusted R^2=0.1390

Table 20.
Adjusted odds ratio (Analysis B-1)

Group	Odds ratio	95%Confidence	
		Lower	Upper
C (Without ppd)	1.000	-	-
B(With some ppd)	0.848	0.794	0.906
A (With ppd)	0.757	0.660	0.870

Table 21 presents the regression coefficients of the logistic regression model in Analysis B-2. The adjusted odds ratio is estimated from the regression coefficients of groups A to C and presented in Table 22.

Table 21.
Regression coefficients of analysis (Analysis B-2)

Variable	Category	Regression coefficient	Standard error
Intercept		-0.6517	-
day/night	day	-0.2245	0.0256
	night	0.2245	0.0256
speed	0km/h - 50km/h	-0.8699	0.0738
	more than 50km/h	0.8699	0.0738
guilt	guilty	0.0152	0.0625
	not guilty	-0.0152	0.0625
age	0-4	-0.1974	0.3197
	5-9	-0.7887	0.1902
	10-18	-0.5422	0.1685
	19-39	-0.2069	0.1271
	40-49	0.1841	0.1624
	50-59	0.3018	0.1341
	60-69	0.3085	0.1258
	70+	0.9407	0.1115
speed X guilt	(0km/h - 50km/h) X first	0.3331	0.0618
	(more than 50km/h) X second	0.3331	0.0618
day/night X age	day X 0-4	0.2406	0.1241
	day X 5-9	0.1286	0.0679
	day X 10-18	0.1102	0.0693
	day X 19-39	-0.0325	0.0520
	day X 40-49	-0.0997	0.0604
	day X 50-59	-0.0405	0.0474
	day X 60-69	-0.1213	0.0426
	night X 5-9	-0.1286	0.0679
	night X 10-18	-0.1102	0.0693
	night X 19-39	0.0325	0.0520
	night X 40-49	0.0997	0.0604
	night X 50-59	0.0405	0.0474
	night X 60-69	0.1213	0.0426
	night X 70+	0.1853	0.0366
speed X age	(0km/h - 50km/h) X 0-4	-0.2888	0.3074
	(0km/h - 50km/h) X 5-9	0.2861	0.1716
	(0km/h - 50km/h) X 10-18	-0.0186	0.1482
	(0km/h - 50km/h) X 19-39	-0.2941	0.1049
	(0km/h - 50km/h) X 40-49	-0.0448	0.1377
	(0km/h - 50km/h) X 50-59	-0.0389	0.1086
	(0km/h - 50km/h) X 60-69	0.1479	0.1023
	(more than 50km/h) X 5-9	-0.2861	0.1716
	(more than 50km/h) X 10-18	0.0186	0.1482
	(more than 50km/h) X 19-39	0.2941	0.1049
	(more than 50km/h) X 40-49	0.0448	0.1377
	(more than 50km/h) X 50-59	0.0389	0.1086
	(more than 50km/h) X 60-69	-0.1479	0.1023
	(more than 50km/h) X 70+	-0.2511	0.0917
guilt X age	guilty X 0-4	-0.3166	0.1294
	guilty X 5-9	-0.2954	0.0722
	guilty X 10-18	-0.1375	0.1015
	guilty X 19-39	0.2996	0.0913
	guilty X 40-49	0.2899	0.1169
	guilty X 50-59	0.1203	0.0957
	guilty X 60-69	-0.0422	0.0910
	not guilty X 5-9	0.2954	0.0722
	not guilty X 10-18	0.1375	0.1015
	not guilty X 19-39	-0.2996	0.0913
	not guilty X 40-49	-0.2899	0.1169
	not guilty X 50-59	-0.1203	0.0957
	not guilty X 60-69	0.0422	0.0910
	not guilty X 70+	-0.0819	0.0765
group	A	-0.1414	0.0458
	B	-0.0094	0.0281
	C	0.1508	0.0290

AIC=24292.762, Adjusted R^2=0.1620

Table 22.
Adjusted odds ratio (Analysis B-2)

Group	Odds ratio	95% Confidence	
		Lower	Upper
C (Without ppd)	1.000	-	-
B(With some ppd)	0.852	0.797	0.911
A (With ppd)	0.747	0.649	0.859

The non-adjusted and adjusted odds ratios are presented in Figure 6 for comparison. Group C is a reference for the odds ratio. There is almost no difference between the odds ratios of Analysis B-1 and Analysis B-2. The adjusted odds ratios of Analysis B-1 and Analysis B-2 are higher than the non-adjusted odds ratio. This means the odds ratio is increased after adjustments. Nevertheless, the odds ratio of group A is lower than that of group B, and the odds ratio of group B is lower than that of group C. We can see that car groups with more pedestrian protection design are less aggressive to pedestrians.

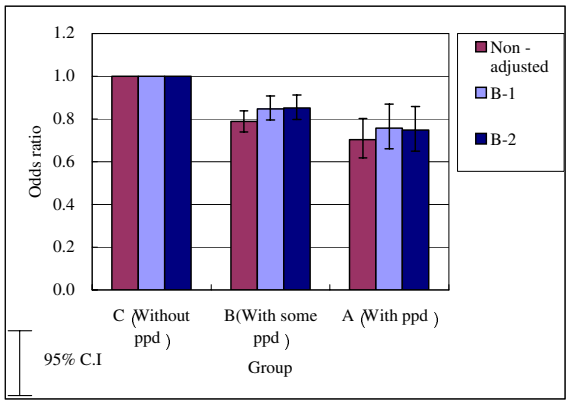

Figure 6. Comparison of non- adjusted and adjusted odds ratios

<u>Adjusted Fatality/severe-injury Rate by Group (Final)</u> - The odds ratio to fatality/severe-injury rate is presented in Figure 7 and Table 23 to express the correlation in Analysis B-1. Because the results of Analyses B-1 and B-2 are almost the same, we consider that Analysis B-1 is a representative result.

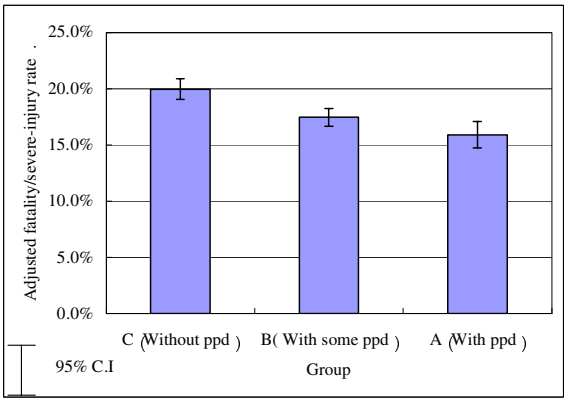

Figure 7. Adjusted fatality/severe-injury rate (Analysis B-1) versus groups of with/without pedestrian head protection performance design

Table 23.
Adjusted fatality/severe-injury rate versus groups of with/without pedestrian head protection performance design

Group	Adjusted fatality/ severe-injury rate	95% Confidence int.	
		Lower	Upper
C (Without ppd)	19.95%	19.07%	20.86%
B(With some ppd	17.45%	16.68%	18.25%
A (With ppd)	15.88%	14.73%	17.10%

CONCLUSION

We investigated the correlation between the pedestrian fatality/severe-injury rate estimated by the accident data and the pedestrian head protection performance evaluation in the JNCAP tests. We also examined the relation between the pedestrian fatality/severe-injury rate and car group with total or partial pedestrian head protection performance design and with or without such design. We adjusted the gender, age, and guilt of the pedestrian and travel speed and by day or night when an accident occurred. The study revealed a correlation between the fatality/severe-injury rate and pedestrian head protection performance levels (1 to 4) in test results, suggesting that passenger cars with better test results protect pedestrians from severe injury better in real-world accidents. We also found that the fatality/severe-injury rate of car models without pedestrian protection design is higher than that of car models with pedestrian head protection design, suggesting that passenger cars with pedestrian protection design are safer than cars without such design in case of pedestrian accidents.

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[2] National Agency for Automotive Safety &

Victim's Aid, March 1996 - March 2004, "New Car Assessment Japan (Pamphlet)".