The Combined Effect of Vehicle Frontal Design, Speed Reduction, Autonomous Emergency Braking and Helmet Use in Reducing Real Life Bicycle Injuries

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ABSTRACT

Vulnerable road users as bicyclists and pedestrians account for a significant share of fatalities and serious injuries in the road transport system. Traditionally, the protection for bicyclists has been addressed by speed management and separating vulnerable road users from motorized traffic. Also, the use of bicycle helmet has been prompted and regulated in some countries. Pedestrian protection by improving the car fontal design has been around since the late 1990th and has proven to be effective in reducing injury risk on pedestrians although the benefits for bicyclists have not yet been evaluated on real world data. Pedestrian detection with Autonomous Emergency Braking (AEB) has also been introduced on the market to prevent and mitigate pedestrian and bicyclist injuries. The purpose of this study was to evaluate the effect of the different interventions promoting safety for vulnerable road users. Emergency hospital reports from approximately 2 000 bicyclists and 1 200 pedestrians between Jan 1st 2003 and March 2014 were included in the study. Hospital reports including injury diagnosis were combined with police data and the vehicle registry in order to obtain detailed vehicle information. Euro NCAP pedestrian test score was correlated with real-life pedestrian and bicyclist injuries. The results showed that on pedestrians, large injury reductions were found comparing low scoring cars (1-9 p) in the Euro NCAP pedestrian test to high scoring cars (>18 p). Also for bicyclists significant injury reductions were found. Focusing on bicyclist's injury level, large reductions were found on all body regions, with the highest reduction on head injuries. The calculated combined effect of speed-reduction, helmet-use and car frontal design was 79%. When the effect of AEB was added, the risk of long term disability decreased by more than 90%.

Keywords: Vulnerable road users, pedestrians, bicyclists, pedestrian protection, combined effect.

1 INTRODUCTION

Vulnerable road users as bicyclists and pedestrians account for a significant share of fatalities and serious injuries in the road transport system [1]. In Sweden, compared to other road users, bicyclists account for the highest proportion of hospital reported injuries [2]. Traditionally, the protection for bicyclists has been addressed by speed management, based on risk curves. The impact of speed on fatality risk in pedestrians hit by cars was estimated by Rosén and Sander [3] who found that the fatality risk at 50 km/h was more than twice as high as the risk at 40 km/h, and more than five times higher than the risk at 30 km/h. In Sweden, lowering of speed restriction is most often combined with other traffic-calming countermeasures, such as smaller roundabouts and speed bumps [4]. Separating vulnerable road users from motorized traffic is also a way to make the road environment safer [5]. The use of separate bicycling lanes is in Sweden estimated to reduce injuries by 20-30 % [4].

Also, the use of bicycle helmet has been prompted and regulated in some countries. The effect of bicycle helmets in Sweden was evaluated by Rizzi et al [6] who found that a helmet could reduce all impairing head injuries by at least 58 % and severe impairing head injuries by 64 %. Helmet use in Sweden is on average 30-35 %, but with great variations between different regions. In 2005 helmet use amongst children <15 years was legislated and helmet use amongst this group is now around 60% [4].

Pedestrian protection by improving the car fontal design was introduced in the late 1990th and has proven to be effective in reducing injury risk on pedestrians [7] although the benefits for bicyclists have not yet been evaluated on real world data. Interestingly, in a study by Fredriksson et al [8], it was found that bicyclists injury locations on the car compared to pedestrians were located further backwards on the car front. The same relationship was also found when including non-fatal injuries, where Fredriksson and Rosén [9] found that bicyclists head impact locations more commonly were from higher impact locations.

Pedestrian detection with Autonomous Emergency Braking (AEB) has also been introduced on the market in order to prevent and mitigate pedestrian and bicyclist injuries. In a prospective study by Hannawald [10] it was estimated that Brake Assist, in combination with a pedestrian protection system could reduce the number of seriously injured persons by 14.3% and fatalities by 11.1%. In another prospective study Rosén et al [11] estimated autonomous braking to reduce fatalities by 40 % and severely injured by 27%. In 2010 autonomous emergency braking with pedestrian detection (AEB) was launched by Volvo Cars on the S/V60 models as optional equipment. Lindman et al [12] estimated the system to have a projected potential to reduce 24% of the pedestrian fatalities.

In 1997 the Euro NCAP started evaluating pedestrian protection by testing legform to bumper, upper legform to bonnet leading edge and headform to bonnet top. In the test, a car can score between 0-36 points. From 1997-2008 the test score was given as a separate star rating, where 1 star = 1-9 points, 2 stars = 10-18 points, 3 stars = 19-27 points, and 4 stars = 28-36 points. Since 2009 the pedestrian test score is included in the overall rating and a minimum of 21 points is required to achieve an overall five star rating [13].

1.2 Aim

The purpose of this study was to evaluate the effect of the different interventions promoting safety for vulnerable road users, using the same population of real life crashes. An additional purpose was to estimate the combined effect of the interventions. Even if the main focus of the different interventions was from a bicycle perspective, also the effect on pedestrians was calculated for reference, because in modern day city-planning interventions usually relate to vulnerable road users as a whole.

2 MATERIAL

Swedish real-life crash data was obtained from the data acquisition system STRADA, which contains police records and hospital admission data. Police data should include all reported road crashes with personal injuries and is the basis for the national statistics. The police data is linked to the national vehicle register, making it possible to identify every specific car model involved in a car to pedestrian crash. Car make, model and model year was linked to their respective Euro NCAP test score. The hospital records in STRADA are collected from emergency hospitals in Sweden (since 2011, all but one). From STRADA injury severity classed according to the Abbreviated Injury Scale (AIS) was obtained. AIS is a globally used severity scoring system that classifies injuries by body region according to its relative importance on a 1-6 point ordinal scale, where 1=minimum and 6=maximum. MAIS represents the one injury with the highest injury severity classification [14].

All crashes between cars and pedestrians and bicyclists included in police records and hospital admission data in STRADA during the period Jan 1st 2003 to March 2014 were selected.. This selection only included pedestrians submitted to hospital, thus pedestrians declared dead at the crash scene were not included in this study. Cases where the patient was hit by parts of the car other than the front was excluded from the study. Only cars tested by Euro NCAP were included. In the end, 1184 pedestrians with 2297 injuries and 2029 bicyclists with 3651 injuries were included in the study. Table 1 and 2 below further describes the characteristics of the material.

Table 1. Mean age and sex of the studied population of injured pedestrians and bicyclists.

	Male	**Female**	**Unknown**	**Mean age**
Pedestrians (n=1184)	781	355	48	46
Bicyclists (n=2029)	1209	784	36	50

Table 2. Number of injuries by injury severity level grouped by pedestrians and bicyclists.

Injury severity	**No. of pedestrians**	**%**	**No. of bicyclists**	**%**
MAIS 1	625	53%	1347	66%
MAIS 2	387	33 %	499	25%
MAIS 3	131	11 %	151	7%
MAIS 4	30	3%	24	1%
MAIS 5	11	1%	8	0%
Sum	1184	100%	2029	100%

3 METHOD

The correlation between pedestrian score and real-life injuries was estimated by comparing three groups of cars (group 1 = 1-9 points, group 2 = 10-18 points, group 3 = >18 points) by the relative difference in injury severity. In this study the injury severity was defined as the proportion of MAIS2+ and MAIS3+ injuries as well as mean risk of permanent medical impairment (mRPMI) on the 1%+ (mRPMI1+), 5%+ (mRPMI5+) level, and 10%+ (mRPMI10+) level. Also bicyclist's injury severity level was investigated comparing the proportion of AIS2+, AIS3+ and mRPMI for different body regions (Head, Lower extremities and pelvis, and Others)

In addition to AIS and MAIS, which are intended to capture the risk of life threatening injuries, this study uses risk of permanent medical impairment (RPMI), which estimates risk of long term disability. RPMI was developed to estimate the risk for a patient to suffer from a certain level of impairment based on the diagnosed injury location and criteria of the Swedish Insurance Companies [15]; [16]. The RPMI matrix is based on approximately 35 000 diagnoses from 20 000 injured car occupants who reported an injury to an insurance company. The injured car occupants were followed for at least 5 years to assess the risk of permanent medical impairment for different body regions and AIS severity levels. The risk is derived from risk matrices based on the location and severity of the injury for 1, 5 and 10% medical impairment (see Appendix A). As reference an AIS2 injury on the lower extremities gives 50% risk of 1% or more medical impairment (RPMI1) but only 3% risk of 10% or more medical impairment (RPMI10). An AIS3 head injury also gives 50% risk of RPMI1 but 35% risk of RPMI10. The risk matrices were developed based on injured car passengers but are considered suitable also for pedestrians [17].

To calculate RPMI on an individual level all injuries to a pedestrian or bicyclists in this study were applied on the risk matrices in Appendix A to obtain values for injury $risk_1$, $risk_2$, $risk_n$, respectively. RPMI per individual was then calculated according to Equation (1). See Malm et al. [15] for a more detailed description of the method.

Equation (1):

$$RPMI = 1 - (1 - risk_1) \times (1 - risk_2) \times (1 - risk_n)$$

To compare the cars in groups 1-3, the proportion on MAIS2+, MAIS3+ and AIS2, AIS3+ as well as the mean RPMI (mRPMI) was calculated for each group. The relative difference between the mean values of RPMI was also calculated and tested by an independent two sample t-test which was conducted for unequal sample sizes and variance. Also a t-test for comparison of proportions was used to investigate any statistical significance in the differences between the groups with regards to proportions of MAIS2+ and MAIS3+ injuries. In order to ensure that the only difference between the groups of cars that could affect injury risk was the pedestrian scoring, controls were made with respect to characteristics of the car, the car drivers, pedestrian or bicyclists as well as the road environment (Appendix B).

The combined effect of Euro NCAP pedestrian score, speed management and bicycle helmet was also investigated with regards to risk of medical impairment. Bicyclists hit by cars in group 1 (1-9 points) on all speed limits, with and without helmets, were compared with bicyclists wearing a helmet that were hit by cars in group 3 (>18 points) on roads with speed limit 20-40 km/h.

Calculations were made in order to estimate the possible effect of crash avoidance and how it would influence the overall result. Crash avoidance was calculated in two ways. First by comparing the take rate (the proportion of cars fitted with AEB with pedestrian detection) in new cars during the same period as the studied material with the rate of cars involved in police reported pedestrian and bicycle injury crashes. Secondly, the odds ratio of pedestrian and bicyclist crashes versus rear-end crashes was compared for cars with and without AEB. Rear-end crashes were in this case considered as non-sensitive to AEB with pedestrian detection and therefore used as the induced exposure. All cars, both in the case and control groups were fitted low speed AEB as to not introduce another AEB-system as a confounding factor. For further reference of induced exposure methods see for example Evans [18], Lie et al. [19] and Rizzi et al. [20].

4 RESULTS

4.1 Individual level

Pedestrians and bicyclists proportion of MAIS2+, MAIS3+ and mRPMI1+, mRPMI5+ and mRPMI10+ were correlated with Euro NCAP pedestrian score. The results is shown in Table 3 and illustrated in Figures 1-4. For pedestrians, all injury levels except MAIS3+ were significantly reduced between car groups 1 and 3, and the largest reduction was found on mRPMI10+. Also for bicyclists reductions were found, although only significant on mRPMI5+.

Table 3. Proportion of MAIS2+, MAIS3+ and mRPMI1+, mRPMI5+ and mRPMI10+ for pedestrians and bicyclists, grouped by NCAP pedestrian score.

	Group 1 (1-9 p)	*Group 2 (10-18 p)*	*Group 3 (>18 p)*	*Rel. diff. 1-2*	*Rel. diff. 1-3*	*p-value (1-3)*	
No. pedestrians	298	764	122				
MAIS2+	51%	47%	41%	-8%	-20%	0,063	*
MAIS3+	18%	14%	9%	-25%	-51%	0,435	ns
mRPMI1+	30%	25%	23%	-18%	-24%	0,008	**
mRPMI5+	17%	13%	10%	-25%	-40%	0,000	***
mRPMI10+	8%	5%	4%	-37%	-56%	0,002	***
No bicyclists	515	1347	167				
MAIS2+	33%	34%	29%	2%	-12%	0,331	ns
MAIS3+	11%	9%	5%	-21%	-57%	0,573	ns
mRPMI1+	18%	19%	15%	1%	-16%	0,110	ns
mRPMI5+	9%	9%	7%	0%	-26%	0,036	**
mRPMI10+	4%	4%	3%	2%	-31%	0,111	ns

* Significant CI90, ** Significant CI95, *** Significant CI99

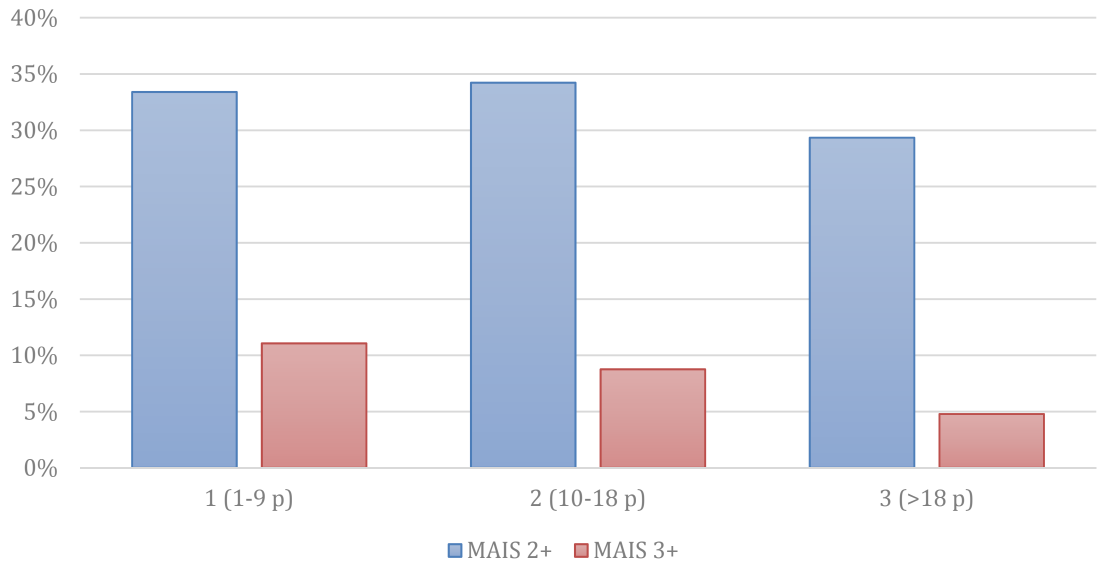

Figure 1. Proportions of bicyclists MAIS2+ and MAIS3+ injuries, grouped by NCAP pedestrian score.

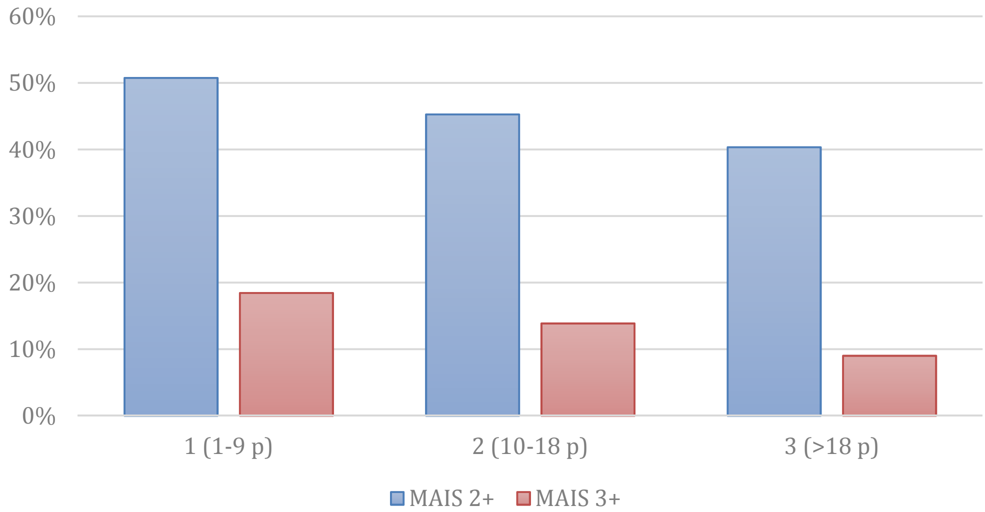

Figure 2. Proportions of pedestrians MAIS2+ and MAIS3+ injuries, grouped by NCAP pedestrian score.

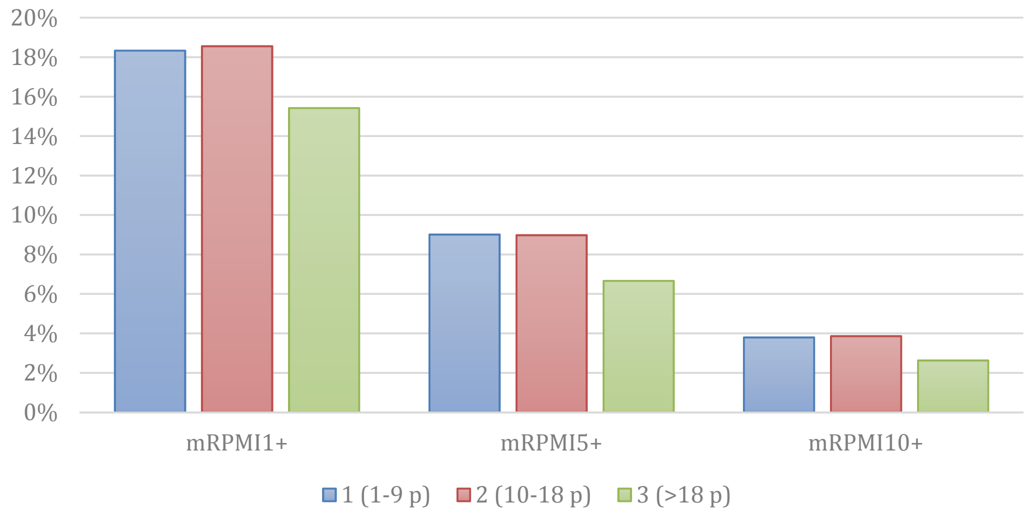

Figure 3. Bicyclists mean Risk of Permanent Medical Impairment (mRPMI) on the 1%+, 5%+ and 10%+ levels grouped by NCAP pedestrian score.

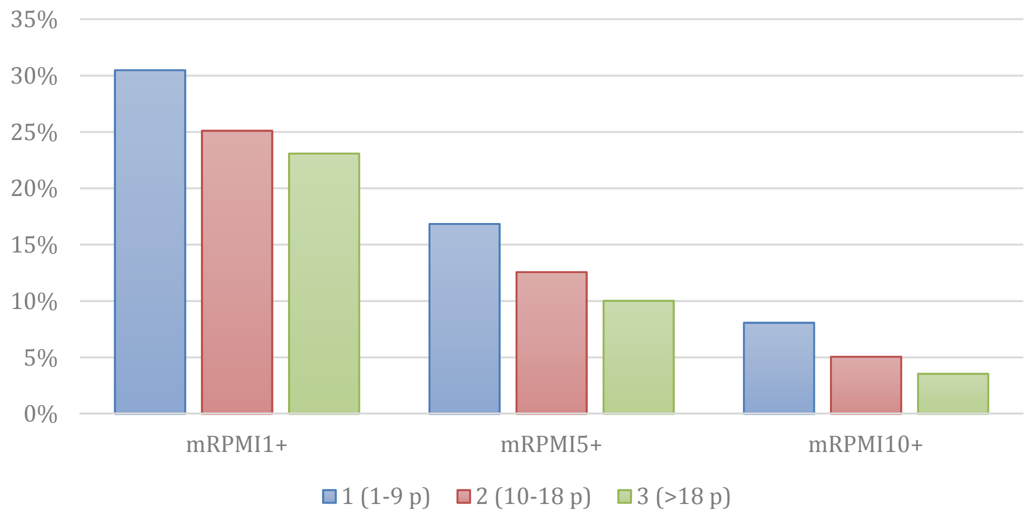

Figure 4. Pedestrians mean Risk of Permanent Medical Impairment (mRPMI) on the 1%+, 5%+ and 10%+ levels grouped by NCAP pedestrian score.

4.2 Bicyclist injury level

The 2029 injured bicyclists sustained a total of 3651 injuries. The distribution of the injuries on RPMI1+ and RPMI10+ level is shown in Figure 5. On the RPMI1 level, the largest shares of impairing injuries are to the upper extremities as well as to the lower extremeties and pelvis. On the RPMI10 level, injuries to the head is the dominating injury category. Looking att the correlation between Euro NCAP scores and bicyclists injuries (see Table 4), it shows that the most common injury category (head) on mRPMI10 level significantly decreases (-57%, p=.059) in a collision with a car in group 3 compared to a car in group 1 (see Figure 6 and Table 3).

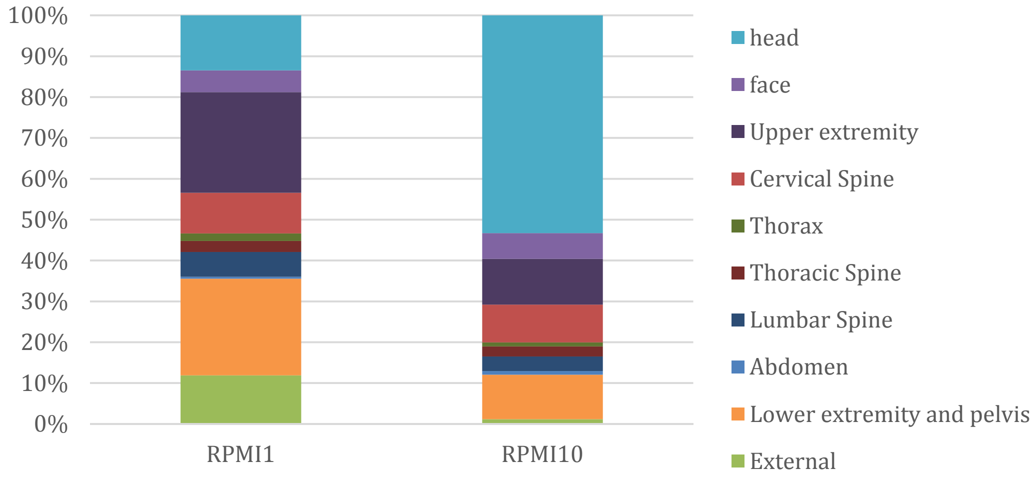

Figure 5. Distribution of bicyclists RPMI1+ and RPMI10+ level injuries.

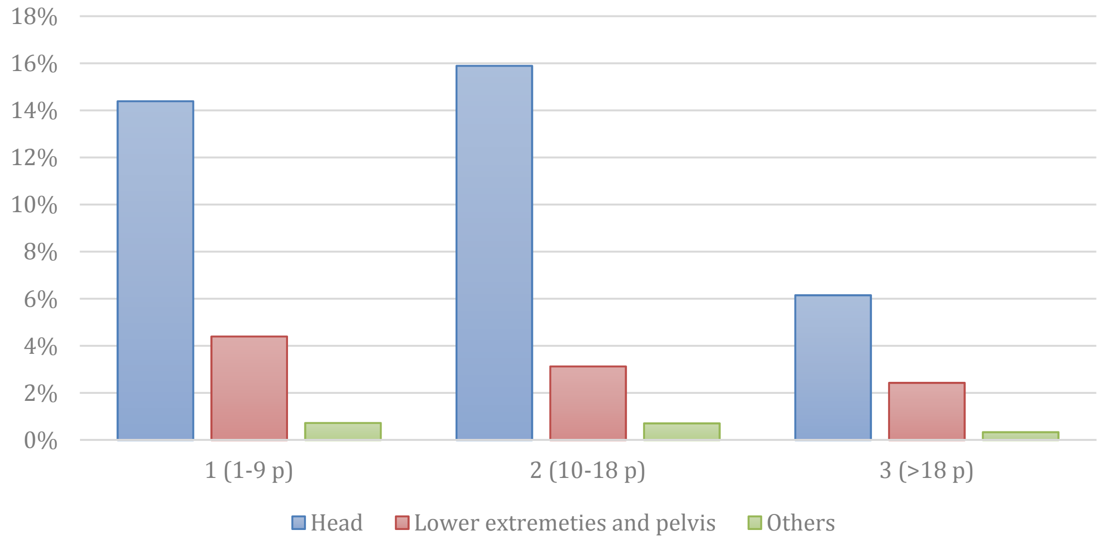

Figure 6. Bicyclists mRPMI10+ for Head, Lower extremeties and pelvis, and Others, grouped by NCAP pedestrian score.

Table 4 shows differences between the different injury severity levels correlated with Euro NCAP pedestrian score. The largest difference is between cars in group 1 and 3 and AIS2+ and AIS3+ head injuries, altough the result is only significant at the AIS 2+ level.

Table 4. Proportion of AIS2+, AIS3+ and mRPMI1+, mRPMI10+ for Head, Lower extremities and pelvis and Others, grouped by NCAP pedestrian score.

	Group 1 (1-9 p)	*Group 2 (10-18 p)*	*Group 3 (>18 p)*	*Rel. diff. 1-2*	*Rel. diff. 1-3*	*p-value (1-3)*	
No. injuries	886	2449	316				
Head							
AIS2+	59%	59%	10%	0%	-83%	0,000	***
AIS3+	31%	30%	5%	-4%	-84%	0,561	ns
mRPMI1+	22%	23%	11%	3%	-50%	0,015	**
mRPMI10+	14%	16%	6%	10%	-57%	0,059	*
Low ext.							
AIS2+	83%	75%	64%	-10%	-23%	0,129	ns
AIS3+	27%	13%	7%	-54%	-74%	0,654	ns
mRPMI1+	47%	43%	38%	-10%	-20%	0,092	*
mRPMI10+	4%	3%	2%	-29%	-45%	0,028	**
Others							
AIS2+	18%	15%	9%	-17%	-49%	0,000	***
AIS3+	3%	2%	1%	-44%	-79%	0,831	ns
mRPMI1+	7%	7%	5%	-2%	-34%	0,000	***
mRPMI10+	1%	1%	0%	-3%	-54%	0,000	***

* Significant CI90, ** Significant CI95, *** Significant CI99

4.3 Combined effect

The combined effect of high performing cars in the Euro NCAP pedestrian test (>18 points), speed limit reduction (20-40 km/h) and helmet use (in the case with bicyclists) is shown in Tables 5 and 6. For bicyclists, the reduction in medical impairment ranged from 44% to 79% depending on level of impairment. The reduction was found significant on impairment levels of at least 5% and 10%.

For pedestrians, the injury reduction of 3-4 star cars in combination with lowered speed limits was 18% for mRPMI1+, 46% for mRPMI5+ and 79% for mRPMI10+, respectively. As for bicyclists, the injury reduction was found significant on impairment levels of at least 5% and 10%.

Table 5. Combined effect of high-performing cars, speed limit reductions and helmet use on bicyclist's injury reduction.

	mRPMI1+	***mRPMI5+***	***mRPMI10+***
Car group 1 (1-9 p), all speed limits (n=515)	18%	9%	4%
Car group 3 (>18 p), 20-40 km/h speed limit, helmet (n=4)	10%	3%	1%
Relative difference	44%	70%	79%
p-value	.354	.015	.001

Table 6. Combined effect of high-performing cars and speed limit reductions on pedestrian's injury reduction.

	RPMI1+	*RPMI5+*	*RPMI10+*
Car group 1 (1-9 p), all speed limits (n=298)	30%	17%	8%
Car group 3, 20-40 km/h speed limit (n=17)	25%	9%	2%
Relative difference	18%	46%	79%
p-value	.369	.006	.000

As for AEB the fitment rate among cars involved in crashes was 3.8% (n=31) while the take rate among new cars was 10%. Thus, the outcome of pedestrian and bicyclist to car injury crashes was 62% less than the expected number using take rate calculation. When rear end crashes were used as a basis for induced exposure calculations, the outcome was 70% lower than the expected number. The crash reduction of AEB with pedestrian detection was, however, not statistically significant (see Appendix C).

5 DISCUSSION

The purpose of this study was to evaluate the effect of different interventions promoting safety for vulnerable road users. An additional purpose was to estimate additional effects of speed limit reduction and helmet use, in order to investigate how close to a safe system for vulnerable road users it is possible to come with a few existing measures. Results showed that high performing cars in the Euro NCAP pedestrian test (> 18 points) reduced the proportion of MAIS2+ and MAIS3+ injuries amongst both bicyclists and pedestrians. However, pedestrians seem to gain larger benefits to a small degree. Reduction of permanent medical impairment (mRPMI) was also shown to correlate with higher Euro NCAP test scores. The relative difference in mRPMI of at least 10% between low performing cars and high performing cars was 31% for bicyclists and 56% for pedestrians. The most commonly injured body region for bicyclists was the head, followed by the leg. These were also the body regions showing the largest injury risk reduction for high scoring cars. As the reduction was significant on all levels, except for AIS3+ where the material was very limited, it implies that pedestrian friendly car fronts are beneficial also for bicyclists. The result of this study was very much in line with previous research of pedestrian friendly car front. The reduction of mRPMI1+ and mRPMI10+ between 1 and two star cars in Strandroth et al. 2011 [3] was 17% and 38% respectively. In this present study the reduction was 18% and 37% but also high performing cars were evaluated and found to reduce mRPMI1+ by 24% and mRPMI10+ by 56%.

The correlation between Euro NCAP test score and injury severity could naturally be subject to confounding factors. In this study there were very few reasons to believe that there were any such factors that would differ between the case and control cars. There are, however, some obvious factors that are controlled through simple calculations and found not to be different (Appendix B).

When combining the effects of high performing cars and speed limit restriction (as well as helmet use among bicyclists), the results showed large significant injury reductions on mRPMI5+ and mRPMI10+ levels on both bicyclists and pedestrians. If also the effect of Autonomous Emergency Braking (AEB) with pedestrian detection (in this study calculated to be 70%) should be added as an independent improvement, the combined effects would be around 90%. This was a first attempt to estimate the effect of Autonomous Emergency Braking with pedestrian detection using an induced exposure approach on police reported crashes. Even though the real injury outcome was 60-70% lower than the expected outcome based on take rates and crash distribution, the numbers are very limited thus the result should be treated with caution. Also, the number of car-to-pedestrian crashes involving cars with pedestrian AEB was too limited to be included in the calculations of combined benefits.

One limitation of this study was the long period of time in which the data was collected. Firstly, the reporting rate from the hospitals in STRADA (as of today, all but one) has increased over the study period, but it is unlikely that this has influenced the results in this study. Secondly, as the road environment evolves over time it could affect the injury severity in car-to-pedestrian crashes. To control that this would not bias the results in this study, mRPMI for low performing cars was calculated for different time periods and found to be constant over time (Appendix B). This study was based on data from Swedish crash data, which makes the results representative only for Swedish conditions and the results can thus not be generalized to other countries. It should also be noted that the risk matrices used to calculate RPMI were initially developed for passenger car occupants. It is clear that different road users have different risk of sustaining a certain injury, however, when the injury is sustained, the risk of not fully recovering from it should be the same. While there is reason to believe that a certain injury should have a certain risk of permanent medical impairment regardless of how that injury was acquired, further research should confirm this.

The overall result of this study shows that when a few preventive actions were combined in order to improve the safety for vulnerable road users as pedestrians and bicycles, it was possible to almost eliminate the risk of severe injuries in car-to-pedestrian crashes. However, it should be stressed that the majority of bicycle injury crashes are single crashes in which other preventive actions is needed in order to eliminate all bicycle injuries.

5.1 Conclusions and Recommendations

- Reductions in long-term injuries were found for both pedestrians and bicyclists between low and high performing cars in the Euro NCAP pedestrian test.
- For bicyclists the higher level of medical impairment was dominated by head injuries, which were reduced by 50-80% comparing low and high performing cars.
- If high performing cars are combined with lowered speeds and helmet-use among bicyclists, pedestrians and bicyclists impairing injuries were reduced by around 70%, also including benefits of AEB the reduction was even greater.
- Further improvements for vulnerable road users safety could be gained by considering bicyclists in the Euro NCAP pedestrian test.

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APPENDIX A – RISK MATRICES FOR PERMANENT MEDICAL IMPAIRMENT

Table 7. Risk of 1% or more permanent medical impairment.

Body region	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Head	8.0%	15%	50%	80%	100%
Cervical spine	16.7%	61%	80%	100%	100%
Face	5.8%	28%	80%	80%	n.a.
Upper extremity	17.4%	35%	85%	100%	n.a.
Lower extremity	17.6%	50%	60%	60%	100%
Thorax	2.6%	4.0%	4%	30%	20%
Thoracic spine	4.9%	45%	90%	100%	100%
Abdomen	0%	2.4%	10%	20%	20%
Lumbar spine	5.7%	55%	70%	100%	100%
External (skin)	1.7%	20%	50%	50%	100%

Table 8. Risk of 5% or more permanent medical impairment.

Body region	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Head	5%	12%	45%	80%	100%
Cervical spine	9.7%	40%	55%	100%	100%
Face	2.4%	10%	60%	60%	n.a.
Upper extremity	4.2%	10%	65%	100%	n.a.
Lower extremity	1.6%	20%	35%	60%	100%
Thorax	0	0,5%	0.7%	15%	15%
Thoracic spine	0.9%	20%	55%	100%	100%
Abdomen	0	0	4.5%	10%	10%
Lumbar spine	1.6%	25%	45%	100%	100%
External (skin)	0.2%	7%	50%	50%	100%

Table 9. Risk of 10% or more permanent medical impairment.

Body region	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Head	2,5%	8%	35%	75%	100%
Cervical spine	2,5%	10%	30%	100%	100%
Face	0,4%	6%	60%	60%	n.a.
Upper extremity	0,3%	3%	15%	100%	n.a.
Lower extremity	0,0%	3%	10%	40%	100%
Thorax	0,0%	0%	0%	15%	15%
Thoracic spine	0,0%	7%	20%	100%	100%
Abdomen	0,0%	0%	5%	5%	5%
Lumbar spine	0,1%	6%	6%	100%	100%
External (skin)	0%	0%	50%	50%	100%

APPENDIX B - Controls

Table 10. Controls, pedestrian age.

Age	Car group 1	%	Car group 2	%	Car group 3	%
0-9	14	5%	35	5%	7	6%
10-24	91	31%	239	31%	52	43%
25-64	131	44%	319	42%	46	38%
65-	62	21%	171	22%	17	14%
Sum	298	100%	764	100%	122	100%

Table 11. Controls, bicyclist age.

Age	Car group 1	%	Car group 2	%	Car group 3	%
0-9	17	3%	36	3%	4	2%
10-24	154	30%	372	28%	41	25%
25-64	289	56%	782	58%	110	66%
65-	55	11%	157	12%	12	7%
Sum	515	100%	1347	100%	167	100%

Table 12. Controls, pedestrian speed limit.

Speed limit	Car group 1	%	Car group 2	%	Car group 3	%
-50	264	89%	656	86%	114	93%
>50	34	11%	108	14%	8	7%
Sum	298	100%	764	100%	122	100%

Table 13. Controls, bicyclist speed limit.

Speed limit	Car group 1	%	Car group 2	%	Car group 3	%

-50	478	93%	1264	94%	161	96%
>50	37	7%	83	6%	6	4%
Sum	516	100%	1349	100%	167	100%

Table 14. Controls, pedestrians, car model year.

Car model year	**Car group 1**	**%**	**Car group 2**	**%**	**Car group 3**	**%**
1997-2000	110	38%	224	30%	2	2%
2001-2005	113	39%	291	39%	16	13%
2005-2013	66	23%	231	31%	103	85%
Sum	289	100%	746	100%	121	100%

Table 15. Controls, bicyclists, car model year.

Car model year	**Car group 1**	**%**	**Car group 2**	**%**	**Car group 3**	**%**
1997-2000	169	34%	357	28%	2	1%
2001-2005	202	40%	547	42%	21	13%
2005-2013	130	26%	384	30%	143	86%
Sum	501	100%	1288	100%	166	100%

Table 16. Controls, pedestrians, driver sex.

Driver sex	**Car group 1**	**%**	**Car group 2**	**%**	**Car group 3**	**%**
Male	201	70%	503	69%	77	66%
Female	86	30%	230	31%	39	34%
Sum	287	100%	733	100%	116	100%

Table 17. Controls, bicyclists, driver sex.

Driver sex	Car group 1	%	Car group 2	%	Car group 3	%
Male	296	58%	821	62%	92	58%
Female	213	42%	504	38%	67	42%
Sum	509	100%	1325	100%	159	100%

Table 18. Controls, pedestrians, driver age.

Driver age	Car group 1	%	Car group 2	%	Car group 3	%
18-24	50	17%	93	12%	8	7%
25-64	170	57%	523	68%	89	73%
65-	78	26%	148	19%	25	20%
Sum	298	100%	764	100%	122	100%

Table 19. Controls, bicyclists, driver age.

Driver age	Car group 1	%	Car group 2	%	Car group 3	%
18-24	63	12%	132	10%	7	4%
25-64	359	70%	969	72%	124	74%
65-	93	18%	246	18%	36	22%
Sum	515	100%	1347	100%	167	100%

Table 20. Controls, pedestrians, light conditions.

Light condition	Car group 1	%	Car group 2	%	Car group 3	%
Unknown	20	7%	38	5%	3	2%
Daylight	149	50%	405	53%	69	57%
Darkness	112	38%	274	36%	40	33%
Dusk/dawn	17	6%	47	6%	10	8%
Sum	298	100%	764	100%	122	100%

Table 21. Controls, bicyclists, light conditions.

Light condition	Car	%	Car	%	Car	%

	group 1		group 2		group 3	
Unknown	26	5%	96	7%	9	5%
Daylight	383	74%	1008	75%	131	78%
Darkness	79	15%	167	12%	17	10%
Dusk/dawn	27	5%	75	6%	10	6%
Sum	515	100%	1347	100%	167	100%

Table 22. Controls, pedestrians, road state.

Road state	Car group 1	%	Car group 2	%	Car group 3	%
Unknown	24	8%	49	6%	7	6%
Dry	141	47%	364	48%	61	50%
Wet	109	37%	249	33%	41	34%
Ice/snow	24	8%	102	13%	13	11%
Sum	298	100%	764	100%	122	100%

Table 23. Controls, bicyclists, road state.

Road state	Car group 1	%	Car group 2	%	Car group 3	%
Unknown	38	7%	116	9%	14	8%
Dry	356	69%	898	67%	111	66%
Wet	105	20%	301	22%	37	22%
Ice/snow	16	3%	32	2%	4	3%
Sum	515	100%	1347	100%	167	100%

Table 24. Controls, pedestrians, mean RPMI of cars in group 1 (1-9 p) grouped by accident year.

Accident year	n	mRPMI1
2003-2010	191	31%
2011-2013	107	29%
Sum	298	30%

Table 25. Controls, bicyclists, mean RPMI of cars in group 1 (1-9 p) grouped by accident year.

Accident year	n	mRPMI1
2003-2010	311	18%
2011-2013	204	19%
Sum	515	18%

Table 26. Controls, pedestrians, mean RPMI of cars in group 1 (1-9 p) grouped by car model year.

Model year	n	mRPMI1
1997-2000	110	31%
2001-2005	113	30%
>2005	66	31%
Sum	289	31%

Table 27. Controls, bicyclists, mean RPMI of cars in group 1 (1-9 p) grouped by car model year.

Model year	n	mRPMI1+
1997-2000	110	31%
2001-2005	113	30%
>2005	66	31%
Sum	289	31%

APPENDIX C – Odds ratio calculation with Induced exposure

	W/Pedestrian detection	***W/O Pedestrian detection***
Bicyclists+Pedestrians	2	52
Rear-end collisions	18	140
OR	0,11	0,37
R	0,30	
E	70%	
delta E	150%	