Evaluation of Seatbelt and Airbag Effectiveness in Reducing Severe and Fatal Injuries in the UAE

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***Abstract*—Seatbelt and airbag are included in most of the vehicles as safety devices to reduce the severity of injury and costs of motor vehicle crashes. The aim of this paper is to study the effectiveness of these two restraints in the UAE based on comparing the observed injuries and fatalities for occupants. This will help identifying most life threating combinations and as such forming policies to reduce injury severity. Detailed crash data analysis was used to assess the seatbelt effectiveness with the two airbag conditions of deployed or not deployed. The seatbelt usage rate and severity of crashes are presented along with Abbreviated Injury Scale and Injury Severity Score for drivers. Chi-square test and odd ratio were used in analysis. The frequencies of severe to fatal injuries are highest in case of seatbelt is not used and airbag is deployed. This study contributed to the injury analysis of various body parts for the four combinations of seatbelt use and airbag deployment. The study concluded that the seatbelt use may result in lesser likelihood of head injuries in case of airbag deployment. It may also result in lesser likelihood of chest injuries whether the airbag is deployed or not.**

***Index Terms*—severe crashes, seatbelt, airbag, effectiveness.**

I. Introduction

Seatbelts as an active and airbags as a passive safety devices are included in most of the vehicles in addition to the other safety devices such as antilock brakes, adaptive cruise control, etc. Seatbelts and airbags deployment for front-end crash [1], are effective devices to reduce the severity of injury and the likelihood of fatality [2]-[18]. Also, they can be regarded as effective means to reduce the cost of motor vehicle crashes [19]-[22]. The effectiveness is commonly measured in literature as the percentage reduction in risk (or probability) of being injured and death with the device (compared to those without it) when involved in a crash [23].

In effectiveness-related studies, and due to the limitations imposed by the lack of the accurate and comprehensive data, it is likely rare to include all factors of potential impact on effectiveness. As such, many studies were primarily based on hypotheses [8], [9], [15] with assumptions to overcome the insufficient availability of data. Effectiveness analysis took various forms such as the use of so-called “double-pair comparison” [24]-[28] and the use of “matched pair-cohort” [29].

The use of the modern three-point seatbelt (without the airbag effect) was estimated to reduce the probabilities of fatality and injury by approximately 40–45% and 80%, respectively [5], [8]. Airbags alone can reduce the risk of driver’s fatality by 8-14% [6], [7], [30], [13]. The combination of both seatbelt and airbag could provide much greater protection, as indicated by [7], reducing the risk of death by 68%. Reference [1] indicated that such combination is 75% and 66% effective in preventing the serious injuries of head and chest, respectively. On the other hand, some studies have indicated that the excessive claims of seatbelt effectiveness may lead to overemphasizing seatbelt use and the negligence of other important aspects and needed policies [31].

The seatbelt use rates influences the measure of seatbelt effectiveness [11]. As such, collecting such rates accurately is rather essential for effectiveness studies. The use of self-reporting seatbelt use by the survivors themselves may be biased [17]. Self-reporting tends to be less accurate with higher usage rate than actual [32]. Direct observation on the other hand, as method to measure the seatbelt use, is quite expensive and requires excessive resources. Actual crash data, although they may not be fully representative of the population, are best available options to carry on accurate effectiveness studies. Nonetheless, one has to careful with the completeness and accuracy of actual crash databases. In many crash reporting systems, such as Kansas Accident Reporting System (KARS) database [23], the UAEU police accident database [33] are lacking essential crash details such as information regarding the airbag deployment. As a result, the effect of airbags on seatbelt effectiveness was not considered in the majority of the studies due to the insufficient availability of data; although airbags can significantly influence the measure of seatbelts effectiveness. Moreover, the deployment of airbag without using the seat belt might increase the injury severity [1].

In the UAE, nearly all (97%) of the traffic safety experts, interviewed in a study by [34], indicated that some detailed crash database would be quite useful for

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their organizations to develop and establish safety policies (51%) and to prioritize safety initiatives (40%). The vehicle safety features, the injury severity score, the nature and type of injury were among the lacking data elements indicated by the experts. Experts commented that seatbelt use data, although exists in current police database, needs to be reviewed and upgraded for better accuracy. Reference [35] on the issue of UAE police data of accident records, indicated that the majority of traffic safety experts (59% of those interviewed in this study) think that the gathered police-type accident information is adequate to deal with traffic safety aspects, while a good portion (30%) have concerns on the adequacy of data.

In conclusion, in order to carry on accurate effectiveness analysis of the seatbelt and airbag deployment, there is imperative necessity to use detailed multi-source data evidence based approach, rather than solely basing the analysis on general aggregate police databases. The measure of seatbelt use and the airbag deployment could be extracted from various sources including the police report (if detailed), vehicle field investigation, patient interviews (if any), and also the injury medical description. Accurate quantitative data can be collected by considering all or part of these sources, which can be used for the purpose of effectiveness analysis.

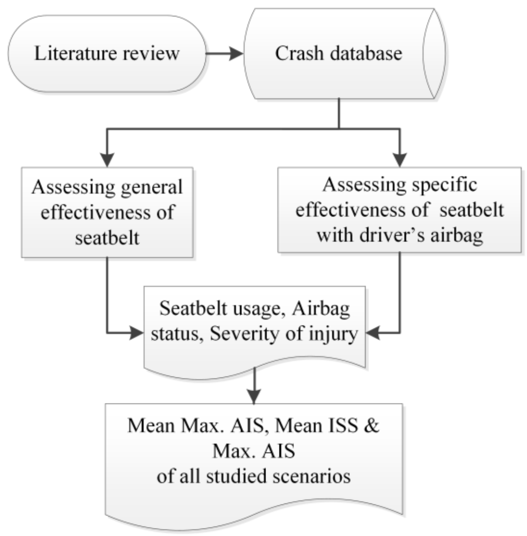

Figure 1. Framework of the research study.

From the literature review, it was noted that the relationship between the use of seatbelt and the potential resulting injury severities of the various body parts was rarely studied. Understanding the specific body part-based effectiveness is rather essential in designing such restraints, especially in the cases of severe and fatal injury crashes. Furthermore, it is not also clear whether the combination of both seatbelt and airbag are effective in reducing the potential severity of the injuries and to what extent. In brief, two research questions are investigated herein:

- Are seatbelts effective in reducing the AIS level of body parts?
- Are seatbelts together with the driver's airbags effective in reducing the AIS level of body parts?

The primary objective of this paper is to evaluate the effectiveness of both seatbelt and airbag reducing the risk of death and injury for occupants involved in motor vehicle crashes. This research is achieved through two major steps. In the first step, all motor vehicle crash data for the drivers and passengers (from multiple sources) were used to estimate the effectiveness of seatbelt alone in reducing fatal and sever injuries. In another step, only the drivers' crash data is used to estimate the effectiveness seatbelt with considering airbag. The actual seatbelt usage and the airbag deployment rates (derived from multiple sources; police, field surveys, occupant surveys and medical reports), and the corresponding detailed Abbreviated Injury Scale (AIS) [36] were used.

The overall framework of the study is presented in Fig. 1. As shown, the study entails two mainlines- one for assessing seatbelt effectiveness in general and another for assessing seatbelt effectiveness together with the airbag condition. The research data from multiple sources of police, field investigation data, passenger interviews and medical records were used to estimate seatbelt usage rates, airbag deployment condition for the various investigated cases, the overall injury severity of crash, and the associated AIS of the various body parts. Additionally, the mean of the maximum AIS, mean of Injury Severity Score (ISS), and the maximum AIS are explored for assessing seatbelt effectiveness with airbag condition.

II. Methodology

The data collection entails collecting data from multiple sources including the collection of the police records, the field investigation of the vehicle and site, the interviews with crash survivors (drivers and/or occupants) and the use the hospital medical records that entail full detailed description of injuries.

This paper uses data of 463 vehicular crashes (excluding the pedestrian or cyclist crashes) that were reported by the police records entailing fatal or serious injuries, and for which there were enough evidence from site, vehicle and driver/occupant interviews to carry on the detailed crash investigation.

In the study, the analysis is performed using SPSS [37] and the Chi-square test [38] of Independence was used to find out the relation between categorical variables. The Odds Ratio (OR) [39] was applied for testing and quantifying the association between variables and the confidence intervals considering the normal approximation were calculated.

III. Results and Discussion

This section, divided into three stages, addresses in detail the effectiveness of the seatbelt and the airbag safety measures; particularly as they relate to the reduction of the injury severity. First, overall seatbelt effectiveness is tackled and discussed. Second, the drivers' seatbelt effectiveness with airbag condition is presented. Third, the findings for the research questions are presented.

TABLE I. DISTRIBUTION OF SEATBELT USE STATUS BY VEHICLE OCCUPANT STATUS

Occupant Status	Seatbelt		Total
	Not Used	Used	
Driver	145 (49%) 58.7%	151 (51%) 69.9%	296 (100%) 63.9%
Passenger	102 (61.1%) 41.3%	65 (38.9%) 30.1%	167 (100%) 36.1%
Total	247 (53.3%) 100%	216 (46.7%) 100%	463 (100%) 100%

** Data in bracket represents row percentage*

A. Seatbelt Effectiveness

Seatbelt usage by occupant, injury severity for seatbelt status, and AIS for seatbelt status are presented in the following sub-sections to discuss the seatbelt effectiveness regardless of the airbag condition. This analysis presented in this section can be used to address the first research question on whether the seatbelts are effective in reducing the AIS levels of body parts.

Seatbelt usage status by occupant: A study by [40] found that only 40.2% of the UAE drivers use seatbelt. The study of [40] was carried out using a self-reporting data collection method in three main cities in the UAE during the year of 2002. Another more recent study by [41] indicated that the percentage of drivers who are frequently not using seatbelts is about 32.5%.

A total of 463 cases of vehicular crashes were considered for analysis. The information on the status of seatbelt usage (used/non used) were collected through injured patients interviews, medical reports, vehicles inspection and police reports. Table I shows the frequency of seatbelt use status by the drivers and passengers. The statistical analysis of the categorical data indicates that there is a significant relationship between the occupants and seatbelt usage [$\chi2$ (1, N=247) = 7.49, p=.006]. 49% of the injured drivers and 61.1% of the injured passengers did not use seatbelts. Overall, 247 occupants did not use seatbelts (out of the total of 463 injured occupants), representing almost about 53.3% of the studied cases.

TABLE II. DISTRIBUTION OF AIS FREQUENCIES FOR SEAT BELT NOT USED (OR USED)

AIS	Head	Face	Neck	Chest	Abdomen	Spine	Upper extremity	Lower extremity	Maximum AIS
1	11 (8)	45 (42)	4 (0)	6 (9)	3 (8)	1 (1)	21 (12)	21 (9)	2 (4)
2	3 (8)	32 (24)	11 (14)	12 (9)	13 (14)	23 (17)	54 (52)	38 (29)	12 (18)
3	19 (18)	15 (13)	10 (3)	35 (30)	9 (9)	8 (5)	11 (17)	47 (48)	41 (39)
4	27 (14)	-	1 (0)	47 (37)	10 (1)	-	-	1 (1)	56 (36)
5	20 (6)	-	-	3 (3)	3 (1)	1 (3)	-	0 (1)	25 (13)
6	102 (91)	1 (0)	2 (5)	22 (19)	10 (11)	-	-	-	111 (106)
9	-	-	-	-	3 (1)	-	-	-	-

** Data in bracket represents seat belt used*

TABLE III. AVERAGE AND STANDARD DEVIATION OF AIS VALUES FOR VARIOUS BODY REGIONS.

Seatbelt status		Head	Face	Neck	Chest	Abdomen	Spine	Upper extremity	Lower extremity	Maximum AIS
Not Used	Mean	4.91	1.72	2.57	3.76	3.56	2.30	1.88	2.26	4.71
	Standard Deviation	1.49	0.86	1.21	1.33	1.59	0.67	0.60	0.78	1.35
Used	Mean	4.90	1.63	3.05	3.68	3.14	2.50	2.06	2.50	4.64
	Standard Deviation	1.61	0.75	1.64	1.42	1.84	1.01	0.60	0.74	1.52

Seatbelt usage status and AIS of body region: Table II demonstrates the severity of injury in different body region by seat belt status. The shaded cells indicate the AIS/body region where the frequencies of not using seat belt were found higher than using it. The majority of severe injuries (AIS of 3+) are particularly related to head, chest and abdomen injuries. The likelihood of head and chest injuries (as represented by the frequencies) are particularly affected by the use of seatbelt; it is clear that the seat belt use would decrease the likelihood of chest and head injuries of AIS of 3+. The number of abdomen injuries with AIS of 4+ is higher without seatbelts as well. The frequencies reported for the various values of maximum AIS (last column) clearly indicate higher likelihood of sustaining AIS of 3+ when the seatbelt is not used.

Estimates of the average (mean) value of the AIS for the various body regions is shown in Table III. This table shows the mean value and the standard deviations of the AIS of all the reported injuries in the various body parts for the two cases of not using/using the seat belt. The table indicates positive impact of seatbelt use (indicated by the light shaded cells) which results in slight reduction of the mean AIS values of head, face, chest and abdomen, and a negative impact (indicated by the dark shaded cells) resulting in slight increase of the AIS for the neck, spine, upper and lower extremity. There is an overall slight positive impact of seat belt use as represented by the mean value of the maximum AIS (last column).

B. Seatbelt Effectiveness with Driver Airbag Condition

In the following sub-sections, the effectiveness of the seatbelt with the driver airbag is evaluated using frequency analysis, injury severity for seatbelt status with airbag deployed, and AIS (head, chest) for seatbelt status with airbag deployed. The analysis presented in this section is utilized to address the second research question on whether the seatbelts together with the driver's airbags are effective in reducing the AIS level of body parts.

Injury severity versus seatbelt status and driver airbag condition: The conducted analysis in this section is particularly limited to the driver's data (where airbag deployment status can be investigated accurately). The total number of studied cases is 296. It is well known that the front airbag usually deploys for frontal impact, and that it may not provide enough protection in cases of side, rear, or rollover crashes.

TABLE IV. DISTRIBUTION OF DRIVER'S SEATBELT STATUS AND AIRBAG DEPLOYMENT CONDITION AND MEAN MAX AIS.

Driver airbag	Seatbelt status		Total
	Not used	Used	
Not fitted	37 (40.2%) 25.5%	55 (59.8%) 36.4%	92 (100%) 31.1%
Mean of MAX AIS	5.14	5.04	
Deployed	66 (56.9%) 45.5%	50 (43.1%) 33.1%	116 (100%) 39.2%
Mean of MAX AIS	4.86	4.54	
Not deployed	37 (50%) 25.5%	37 (50%) 24.5%	74 (100%) 25%
Mean of MAX AIS	4.51	4. 32	
Unknown	5 (35.7%) 3.4%	9 (64.3%) 6%	14 (100%) 4.7%
Mean of MAX AIS	4.6	5.44	
Total	145 (49%) 100%	151 (51%) 100%	296 (100%) 100%

***** Data in bracket represents row percentage

Table IV illustrates the driver's seatbelt status and driver's airbag condition cross tabulation. It indicates that in 66 cases (22.3%, n=296), the drivers did not use the seatbelt and yet the steering wheel airbags were deployed. This situation could be life-threatening, as it may result in excessive airbag impact force on the drivers without the seatbelt restraints.

The odds of seatbelt not used to seatbelt used in case of airbag deployed or not deployed is (66+37/50+37) =1.18. As evident from this table, it is clear that not using seatbelt will result in higher values of the mean of maximum sustained AIS. For instance, not using seatbelt in case of airbag deployment results in mean max AIS value of 4.86 as compared to 4.54 in the case of used seatbelts. The same is true for the case of airbag not deployed.

The odds of airbag deployed to not deployed in case of seatbelt used or not used is (66+50/37+37) = 1.56 indicating higher likelihood of airbag deployment. As evident from this table, it is clear that the cases of airbag deployment will result in higher values of the mean of maximum sustained AIS. For instance, airbag deployment in case of not using seatbelt results in mean max AIS value of 4.86 as compared to 4.51 in the case of airbag not deployed. The same is true for the case of seatbelt is used.

From the above, it can be concluded that not using seatbelt with airbag deployment is likely to be associated with higher levels of injury. This life threatening situation has a frequency of occurrence equal to 66/296= 0.22.

The minimum safe distance for a protective airbag deployment is around 25 cm. The space between the steering wheel and the driver seat is about 50 cm (without driver) and about 90 cm for the front passenger seat. If the driver is seated, the minimum safe space for airbag deployment might not be maintained, especially for overweight short drivers not wearing seatbelt. Due to the crash impact in cases without seatbelt usage, the driver moves fast towards the steering wheel, reducing the safe minimum space needed for a protective airbag deployment. This explains the increased injury severity in cases of seatbelt not used and deployed airbags.

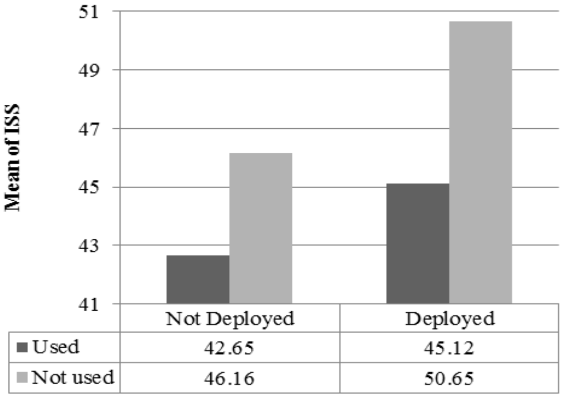

Figure 2. Mean ISS versus seatbelt and airbag deployment status.

Fig. 2 illustrates the relationship between the mean ISS [the mean of the ISS values of all the cases within one category] versus the seatbelt and airbag deployment status. As shown, the used seatbelt cases reported lesser mean ISS. The least mean ISS (45.12) corresponds to the category of used seatbelts and deployed airbags. The highest mean total ISS (50.65) corresponds to the category of not used seatbelts and deployed airbags. It is evident that using seatbelt reduces the overall injury severity score (ISS).

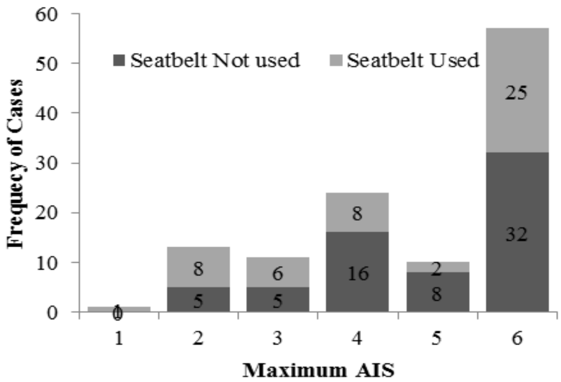

Figure 3. Frequency distribution of Max. AIS with seatbelt status and driver's airbag deployed.

Fig. 3 illustrates the frequencies of the cases in each of the Max AIS categories. This figure is limited to the cases of drivers with deployed airbags only (n=116). It is evident that for Max AIS of 3+, the reported cases without seatbelts are higher than the ones with seatbelt usage. That is, the possibility of sustaining higher injury level is higher for the cases without seatbelt use.

Head and Chest AIS versus seatbelt status and driver airbag condition: In this section, the effectiveness of seatbelt with respective to the airbag deployment is studied for head and chest injuries only. As previously indicated in Table III, the most severe injuries are sustained by the head and chest. The mean of the maximum AIS of these two body parts are particularly influenced by the seatbelt and airbag status. As such, careful examination of such injuries is deemed necessary. According to [1], the combination of using seatbelt with airbag is 75% and 66% effective in preventing the serious injuries of head and chest, respectively. Excessive claims of effectiveness of such restraints may lead to overemphasizing usage and the negligence of other important aspects and needed policies [31].

TABLE V. HEAD AND CHEST AIS INJURY LEVEL FREQUENCIES WITH VARIOUS SEATBELT AND AIRBAG DEPLOYMENT

AIS	HEAD				CHEST			
	Seatbelt not used		Seatbelt used		Seatbelt not used		Seatbelt used	
	Airbag deployed	Airbag not deployed	Airbag deployed	Airbag not deployed	Airbag deployed	Airbag not deployed	Airbag deployed	Airbag not deployed
1	2	2	1	2	12	1	15	4
2	1	0	3	1	9	2	5	2
3	3	3	2	6	3	6	1	4
4	6	2	2	2		7		5
5	5	1	1	0		-		-
6	30	16	24	12		4		2

Table V shows the frequencies of various AIS injury levels among drivers with various seatbelt and airbag deployment status. The following result statements can be drawn from careful examination of such frequencies:

- In case of seatbelt is not used and airbag is deployed, frequencies of severe to fatal head injuries (AIS=4+) are significantly higher than the case of airbag not deployed.
- In case of seatbelt is used and airbag is deployed, frequencies of fatal head injuries (AIS=6) are significantly higher than the case of airbag not deployed.
- Minor chest injuries (AIS=2-) are more in case of seatbelt not used and airbag deployed compared to case of airbag non deployment. More severe chest injuries (AIS=3+) are encountered when seatbelt is not used and no airbag deployment; as well as same for seatbelt is used and no airbag deployment.
- In case of airbag is deployed, frequencies of severe to fatal head injuries (AIS=4+) are significantly higher in case of seatbelt not used as compared to case of seat belt used. Only minor to moderate chest injuries are encountered, where minor chest injuries (AIS=2&3) are slightly more in case of seatbelt not used as compared to case of seatbelt used.
- In case of airbag is not deployed, frequencies of fatal head injuries (AIS=6) are slightly higher in case of seatbelt not used as compared to case of seat belt used. More severe chest injuries (AIS=3+) are encountered in case of seatbelt not used as compared to seatbelt is used.

TABLE VI. BEST COMBINATION OF COUNTERMEASURES FOR VARIOUS AIS LEVELS (AIRBAG DEPLOYMENT STATUS)

Injury level	AIS	HEAD				CHEST			
		Airbag deployed		Airbag not deployed		Airbag deployed		Airbag not deployed	
		Seatbelt not used	Seatbelt used	Seatbelt not used	Seatbelt used	Seatbelt not used	Seatbelt used	Seatbelt not used	Seatbelt used
Minor	1-2	3	4	2	3	21	20	3	6
Moderate	3-4	9	4	5	8	3	1	13	9
Severe-Fatal	5-6	35	25	17	12			5	2
Overall best									

From the above results, it is concluded that frequencies of severe to fatal head injuries (AIS=4+) are higher in case of seatbelt not used compared to seatbelt used. The frequencies of such severe to fatal injuries are highest in case of seatbelt is not used and airbag is deployed. Additionally, Minor chest injuries (AIS=2-) are more in case of airbag deployment compared to case of airbag non deployment regardless of seatbelt status. More severe chest injuries are encountered in case of no airbag deployment regardless of seatbelt status as well.

In general, frequencies of severe to fatal injuries (AIS=4+) are significantly higher in case of airbag deployment compared to non-deployment and Minor chest injuries (AIS=2-) are more in case of airbag deployment compared to case of airbag non deployment. More severe chest injuries are encountered in case of no airbag deployment. It could be concluded that airbags are effective counter measures in reducing severe chest injuries, but inversely they could contribute to more minor chest injuries and higher chances of severe and fatal head injuries.

C. *Best and Worst Seatbelt and Airbag Combinations*

For better comprehension of the previous results, Table VI is formed by congregating in the minor (AIS 1-2), moderate (AIS 3-4) and severe/fatal (AIS 5-6) injury groups. Comparative analyses of the groups’ frequencies were used to identify the best combinations of seatbelt and airbag for each injury group. Finally, the overall best combinations for head and chest injuries were identified.

The best combination is identified by selecting the combination that results in lesser frequencies of injuries. For instance, with reference to Table VI, for head injuries, and airbag deployed condition, the combination of (seatbelt used) is identified to be "best" for severe and fatal head injuries, as it results in lesser frequencies (25) as compared to (35) if the seatbelt is not used. Similarly, the best combination for moderate chest injuries when airbag is not deployed is the seatbelt used, as it results in lesser frequencies (9) as compared to (13) when the seatbelt is not used. Opposite to the best combination, the worst one is identified by selecting the combination that results in higher frequencies of injuries.

From Table VI, it can be concluded that the seatbelt use generally results in lesser likelihood of head injuries in case of airbag deployment. It results in lesser likelihood of severe head injuries in case of airbag not deployed. Minor to moderate head injuries are likely higher in case of seatbelt use when airbag is not deployed. It also results in lesser likelihood of chest injuries whether the airbag is deployed or not.

IV. Concluding Remarks

This study provides the analysis of the effectiveness of seatbelts, and the synthesized effectiveness of seatbelts and airbags based on comparing the observed injuries and fatalities for occupants protected by the various systems, although the differences in fatality- and injury-reducing effectiveness can be masked by a multitude of factors not directly related to the airbags or seatbelts systems [5]. For this, the detailed crash database is used to conduct the assessment of the effectiveness of seatbelts and airbags. The data was collected from multiple sources including police records, vehicles and site investigation, crash survivor interviews, and hospital records.

Some previous behaviour studies relied on self-reported seatbelt use [40], [41]. In these studies, estimates of usage among drivers and occupants were based on self-reported or claimed use rather than whether seatbelts were actually used. In this study, the actual seatbelt use and the airbag deployment were extracted from various sources including the police report, vehicle field investigation, patient interviews (if any), and also the injury medical description. It was found that 49% of the injured drivers and 61.1% of the injured passengers (including rear passengers) did not use seatbelts which is more than reported values in previous studies that are based on self-reported behavior studies data.

This study concluded that the severity of injuries and fatalities by road traffic crash is reduced by using seatbelts, and airbag deployment with seatbelt usage. The results show that for severe crashes (AIS 3+), use of seatbelt reduces the injury severity of AIS head and chest. For minor crashes (AIS 2-), the use of seatbelt increases the injury severity of AIS abdomen. However, use of seatbelt reduces overall maximum AIS severity. Also the results indicated that nearly 57% of the drivers didn't use seatbelt during airbag deployment, which is an alarming issue because airbag deployment without using seatbelt increases the injury severity. Additionally, it is evident that using seatbelt while deploying airbag reduces the overall injury severity score (ISS). For deployed airbag while using seatbelt, the mean ISS is 45.12 compared to 50.65 while not using seatbelt. Also it is concluded that the seatbelt use generally results in lesser likelihood of head injuries in case of airbag deployment. It results in lesser likelihood of severe head injuries in case of airbag not deployed as well. It also results in lesser likelihood of chest injuries whether the airbag is deployed or not.

This study is limited in the sense it is based on investigating severe and fatal crashes only. It should be clear that such detailed data and crash investigation is quite costly, reaching almost few thousands of dollars for each investigated crash. As such, and due to the limitation of resources it was decided to emphasize only severe and fatal crashes. The significances around many estimates are relatively wide given the limited sample size available in the detailed database. Due to such limitation of data availability, it is not possible to define a model for assessing the association between variables. While the study proves that safety of occupant in motor vehicles can be improved using the seatbelts with airbags, further advances in occupant protection will require more data. Evidence resulting from this research can be used to provide a conceptual basis to the planned introduction and adoption of appropriate public policies, improvements in vehicle and restraint design, and adaptation of occupants' attitudes and behavior to further increase the protection of occupants.

References

[1] Air Bags and On-Off Switches Information for an Informed Decision, National Highway Traffic Safety Administration, U.S. Department of Transportation, Publication DOT HS 811 264, 2010.

[2] Final Regulatory Impact Analysis: Amendment to Federal Motor Vehicle Safety Standard 208: Passenger Car Front-seat Occupant Protection, Publication No. DOT HS 806 572. National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, 1984.

[3] Third Report to Congress: Effectiveness of Occupant Protection Systems and Their Use, National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, D.C., 1996.

[4] Fourth Report to Congress: Effectiveness of Occupant Protection Systems and Their Use, DOT Report Number HS 808 919. National Highway Traffic Safety Administration, U.S. Department of Transportation ,Washington, D.C., 1999.

[5] Fifth / Sixth Report to Congress: Effectiveness of Occupant Protection Systems and Their Use, National Highway Traffic Safety Administration, U.S. Department of Transportation, Publication DOT HS 809 442, Washington, D.C., 2001.

[6] E. R. Braver, S. A. Ferguson, M. A. Greene, A. K. Lund, "Reductions in deaths in frontal crashes among right front passengers in vehicles equipped with passenger air bags," *JAMA*, vol. 278, no. 17, pp. 1437-9, Nov. 1997.

[7] P. Cummings, B. McKnight, F. P. Rivara, and D. C. Grossman, "Association of driver air bags with driver fatality: A matched cohort study," *BMJ*, vol. 324, no. 7346, pp. 1119-1122, 2002.

[8] P. Cummings, J. D. Wells, and F. P. Rivara, "Estimating seat belt effectiveness using matched-pair cohort methods," *Accident Analysis and Prevention*, vol. 35, no. 1, pp. 423–433, 2003.

[9] L. Evans, "The effectiveness of safety belts in preventing fatalities," *Accident Analysis and Prevention*, vol. 18, no. 3, pp. 217-227, 1986.

[10] L. Evans, "Restraint effectiveness, occupant ejection from cars, and fatality reductions," *Accident Analysis and Prevention*, vol. 22, no. 2, pp. 167–175, 1990.

[11] L. Evans, "Safety-belt effectiveness: The influence of crash severity and selective recruitment," *Accident Analysis and Prevention*, vol. 28, no. 4, pp. 423–433, 1996.

[12] S. W. Johnson and J. Walker, "The crash outcome data evaluation system (CODES)," *National Center for Statistics and Analysis, National Highway Traffic Safety Administration*, Publication DOT HS 808 338, 1996.

[13] C. J. Kahane, "Fatality reduction by air bags: analysis of accident data through early," DOT Report Number HS 808 470.Washington, DC: National Highway Traffic Safety Administration, 1996.

[14] B. H. Kaplan and R. A. Cowley, "Seatbelt effectiveness and cost of non-compliance among drivers admitted to a trauma centre," *The American Journal of Emergency Medicine*, vol. 9, no. 1, pp. 143–149, 1991.

[15] F. P. Rivara, T. D. Koepsell, D. C. Grossman, and C. Mock, "Effectiveness of automatic shoulder belt systems in motor vehicle crashes," *JAMA*, vol. 283, no. 21, pp. 2826–2828, 2000.

[16] L. S. Robertson, "Estimates of motor vehicle seat belt effectiveness and use: Implications for occupant crash protection," *American Journal of Public Health*, vol. 66, no. 9, pp. 859-864, 1976.

[17] L. S. Robertson, "Bias in estimates of seat belt effectiveness," *Injury Prevention*, vol 8, no. 263, 2002.

[18] D. C. Viano, "Restraint effectiveness, availability and use in fatal crashes: implications to injury control," *J. Trauma*, vol. 38, no. 4, pp. 538-546, 1995.

[19] W. M. Marine, E. M. Kerwin, E. E. Moore, *et al.*, "Mandatory seatbelts: Epidemiologic, financial, and medical rationale from the Colorado matched pairs study," *J. Trauma*, vol. 36 no.1, pp. 96–100, 1994.

[20] T. R. Miller, "Costs of safety belt and motorcycle helmet nonuse," *Testimony to Subcommittee on Surface Transportation, House Committee on Public Works and Transportation*, March 3, 1994.

[21] T. R. Miller, D. C. Lestina, and R. S. Spicer, "Highway, accident analysis crash costs in the united states by driver age, blood alcohol level, victim age and restraint use," *Accident Analysis and Prevention*, vol. 30, no. 2, pp. 137–150, 1998.

[22] D. E. Nelson, T. D. Peterson, T. L. Chorba, O. J. Devine, and J. J. Sacks, "Cost savings associated with increased safety belt use in Iowa, 1987–1988," *Accident Analysis and Prevention*, vol. 25 no. 5, pp. 521-528, 1993.

[23] I. Ratnayake, "Effectiveness of seat belts in reducing injuries," Ph.D. Thesis, Mack-Blackwell Transportation Center, 4190 BELL, University of Arkansas, Fayetteville, AR 72701, 2007.

[24] S. Dissanayake and I. Ratnayake, "Estimation of seat belt effectiveness values using double pair comparison method based on state highway crash data," *Advances in Transportation Studies*, vol. 13, pp. 67-76, 2007.

[25] L. Evans, "Double-pair comparison—a new method to determine how occupant characteristics affect fatality risk in traffic crashes," *Accident Analysis and Prevention*, vol. 18, no. 3, pp. 217-227, 1986.

[26] C. J. Kahane, "Fatality and injury reducing effectiveness of lap belts for back seat occupants," Paper No. 870486, Society of Automotive Engineers, Warrendale, PA, 1987.

[27] C. J. Kahane, "Fatality reduction by safety belts for front seat occupants of cars and light trucks, updated and expanded estimates based on 1986 – 99 FARS data," Publication DOT HS 809 199. NHTSA, U.S. Department of Transportation, 2000.

[28] C. Morgan, "Effectiveness of Lap/Shoulder Belts in the Back Outboard Seating Positions," Publication DOT HS 808 945. NHTSA, U.S. Department of Transportation, 1999.

[29] P. Cummings, B. McKnight and N. S. Weiss, "Matched-pair cohort methods in traffic crash research," *Accident Analysis and Prevention,* vol. 35, no. 1, pp. 131–141, 2003.

[30] S. A. Ferguson, A. K. Lund and M. A. Greene, "Driver fatalities in 1985-1994 air bag cars. Arlington," VA: Insurance Institute for Highway Safety, pp. 1-9, 1995.

[31] L. S. Robertson, "Further reflections on the seatbelt use and effectiveness issue," *Injury Prevention*, vol 9, no. 3, pp. 284-285, 2003.

[32] D. E. Nelson, "Validity of self-reported data on injury prevention behavior: Lessons from observational and self-reported surveys of safety belt use in the US," *Injury Prevention*, vol. 2, no. 1, pp. 67-69, 1996.

[33] Y. Hawas, J. Thomsen, D. Alam, and N. Ahmed, "In-depth Investigation of Severe and Fatal Roadway Crashes in the Emirate of Abu Dhabi-UAE," in *Proc. 15th International Conference on Road Safety in Four Continents*, Abu Dhabi, UAE, March 2010.

[34] Y. E. Hawas, M. Khan, and M. Maraqa, "Analysis of the effectiveness of crash database system in united arab emirates," *Journal of Transportation Safety & Security*, vol. 4, no. 3, pp. 225-243, 2012.

[35] M. N. Hassan, Y. E. Hawas, and M. Maraqa, "A holistic approach for assessing traffic safety in the UAE," *Accident Analysis and Prevention*, vol. 45, pp. 554– 564, 2012.

[36] Association of the Advancement of Automotive Medicine (AAAM), *The Abbreviated Injury Scale 1990 Revision*, Des Plaines, IL, AAAM, 1998.

[37] SPSS, *SPSS Statistics for Windows, Version 17.0*, Chicago: SPSS Inc, 2008.

[38] R. F. DeVellis, "Inter-rater reliability," in *Encyclopedia of Social Measurement*, Ed. Kempf-Leonard K, Cambridge: Academic Press, 2005, pp. 317–322.

[39] W. Lowe, "Rare Events Research," in *Encyclopedia of Social Measurement*, Ed. Kempf-Leonard K, Cambridge: Academic Press, 2005, pp. 293-297.

[40] A. Bener, T. Özkanc, and T. Lajunenc, "The driver behaviour questionnaire in arab gulf countries: Qatar and united arab emirates," *Accident Analysis and Prevention*, vol. 40, no. 4, pp. 1411-1417, 2008.

[41] N. A. Naser, Y. Hawas, and M. Maraqa, "Characterizing driver behaviors relevant to traffic safety: A multi-stage approach," *Transportation Safety & Security*, vol. 5 no. 4, pp. 285-313, 2013.

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