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Analysis of risk factors associated with severe injury in child pedestrian-vehicle collision in Ghana

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Abstract

The alarming rate at which children are being killed on our roads, coupled with lack of empirical studies that look at the risk factors associated with child pedestrian injury severity on the roads in Ghana has motivated this study. This study contributes to the existing knowledge by examining the risk factors associated with child pedestrian injury severity in the event of vehicle crashes. A binary logistic regression model was applied to child pedestrian-vehicle crash data obtained from the Building and Road Research Institute (BRRI) of Council for Scientific and Industrial Research (CSIR), Ghana. Out of the 1449 child pedestrian crash records, 63% were classified as severely injured. The results from the developed model indicate that a child's gender and age, driver's gender and age, pedestrian location, vehicle type, time of day, day of week and road width significantly influence the likelihood of a child pedestrian sustaining severe injury in the event of vehicle crash. The practical implications of this study are that parents and guardians need to take personal responsibilities in providing the needed support to their children when crossing or walking along the road. In addition, drivers should be educated on conscious driving in areas where pedestrians, particularly children are crossing or walking along road side.

Keywords: Pedestrian; child safety; injury severity; logitic regression; odds ratio; Accra

1. Introduction

It is often said that young people have the power to change the world and the future of a country depends on its youth. Hence, we cannot afford to lose our children to road crashes. Globally, over 1.2 million individuals die annually and 20 to 50 million suffer injuries due to road traffic crashes (WHO 2009). A report by (WHO 2013) stated that 27% of global road traffic deaths were amongst pedestrians and cyclists who have not been considered in the formulation of transport and planning policies over the years. Thus, pedestrians and cyclists strive with drivers for road space at

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their own risks. The situation is on the rise particularly in the developing countries. Pedestrians and drivers in developing countries fail to adhere to traffic rules thereby posing higher risks for pedestrians' safety (Hamed 2001). In the developing countries, over 85% of fatalities and 90% of disability attuned life years are lost as a result of road traffic injuries (Nantulya and Reich 2002). Road crashes involving pedestrians are said to be the major cause of traffic injury deaths in Ghana. Agyemang et al. (2017) reported that pedestrians still remain the class of road users with the utmost share of fatalities constituting about 39.5% of all traffic fatalities in Ghana.

Road traffic crashes affects all age groups however, it is remarkably high among the youth. Globally, 35% of pedestrian crashes, which are children, constitute about 300,000 fatalities annually (WHO 2009). Children are the most vulnerable group in any pedestrian-vehicle crash. The ability to exercise due diligence could be premised on physical, emotional and cognitive capabilities. Unfortunately, children may not have developed these commendable abilities. According to Simpson et al. (2003), children are more inclined to making unsafe crossings than adults as a result of their inability to assess the road environment holistically. A number of factors have been identified to influence injury severity in child pedestrian-vehicle collision in many countries. These factors include gender, age and action of the child pedestrian, driver's gender and age, vehicle type, road width, time of day, light condition and day of week (Scott 1986, DiMaggio and Durkin 2002, Ballesteros et al. 2004, Chen et al. 2012).

In Ghana, a number of studies have been conducted in the area of pedestrian safety (Damsere-Derry et al. 2010, Aidoo et al. 2013, Akaateba et al. 2015, Amoh-Gyimah et al. 2016). For instance, Damsere-Derry et al. (2010) examined severity of pedestrian injury on a section of Accra-Kumasi road whilst Aidoo et al. (2013) assessed the effect of road and environment on pedestrian hit and run crashes. In a more recent study, Amoh-Gyimah et al. (2016) examined the effect of road and environmental characteristics on pedestrian-vehicle crash injury severities in the whole of Ghana. Despite the number of studies conducted in the area of pedestrian safety in Ghana, there is limited literature specifically focusing on child pedestrians crashes. Such specific information is important to support policies pertaining to child pedestrian safety. This study addresses this gap in the literature by providing valuable insights into the risk factors associated with severe injuries to child pedestrians when involved in vehicle crashes.

2. Material and Methods

2.1. Model specification

The binary logistic regression model was employed to describe the effect of all the explanatory variables (covariates) on the injury severity of child pedestrian when involved in road crash. The dependent variable for this study is the injury severity which is modelled as a dichotomous outcome: severe (coded as 1) and non-severe (coded as 0). The binary logistic regression model can be defined in general as (Agresti 2007):

$$\log\left[\frac{P(Y=1)}{1-P(Y=1)}\right]=\log\left(\frac{\pi}{1-\pi}\right)=\alpha+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_k x_k \tag{1}$$

where $P(Y=1)=\pi$ defines the probability of a child pedestrian being severely injured whereas $1-\pi$ defines the probability of a child pedestrian not severely injured when involved in a vehicle crash. The model predicts the probability (π) of a child pedestrian sustaining severe injury when involved in a vehicle crash. In equation (1), α and β_j*'s* are model parameters corresponding to the intercept and the coefficients for each explanatory variable, respectively. The Maximum Likelihood Estimation (MLE) method was used to find the point estimate for α and β_j. Since a log transformation is used in (1), the interpretation of the model results is done on the exponential back-transformation of the estimated model parameters. The back-transformed parameters is referred to as an odds ratio (Agresti 2007). In relation to this study, an odds ratio represents the probability a child pedestrian sustained severe injury when involved in a vehicle crash with respect to a change in the independent variables incorporated into the model.

2.2. Data description

The study is limited to the child pedestrian-vehicle crashes that occurred in Greater Accra region, Ghana over a period of 8 years (2009-2016). The Greater Accra region is one of the 10 administrative regions in Ghana. It is the most densely populated region as it contains Ghana's major industrial and commercial centres. Greater Accra Region has the highest number of vehicle fleet and has consistently recorded the highest prevalence of road traffic accidents in Ghana (Agyemang et al. 2017). The study focused on pedestrian-vehicle crashes involving children between the ages of 5 years and 17 years. The data for the study were obtained from the Building and Road Research Institute (BRRI) of Council for Scientific and Industrial Research (CSIR), Ghana. In all, 1449 observations with missing values for some variables were analysed. From the data, variables which posed as risk factors were identified.

The pedestrian injury severity is classified into three levels: fatal, hospitalised and injured not-hospitalised. A fatal injury describes a situation where a pedestrian dies within 30 days of the crash; hospitalised describes a situation where the pedestrian was hospitalised for at least 24 hours for medical attention whereas injured not-hospitalised describes a situation where the pedestrian sustained little or no injury after the crash and may require less than 24 hour hospital treatment. Though the injury severity as described has three outcomes, they were categorised into two: severe and non-severe injury. The severe injury constitute the fatal and hospitalized injury whereas the non-severe injury constitute non-hospitalized injury. Thus, the dependent or response variable considered has two outcomes: severe injury (coded as 1) and non-severe injury (coded as 0). The independent variables considered in the model reflect the socio-demographic characteristics of the driver and the child pedestrian, environmental characteristics, vehicle characteristics, road characteristics, and temporal characteristics.

Over the study period, a total of 1449 child pedestrian-vehicle crashes were recorded and 63% of this was classified as severe injury whiles 37% was classified as non-severe injury. The descriptive statistics of all the variables considered in this study are summarised in Table 1. More male child pedestrians (67%) were involved in vehicle collisions that resulted in severe injuries as compared to females (59%). Severe injuries were found to be higher (67%) in children pedestrian below 12 years as compared to older children (54%). Severe injuries were found to be higher (68%) among child pedestrians crossing roads compared to those doing other action (walking along the road edges and footpath). Most (66%) of the severe injuries associated with child pedestrians were caused by male drivers and most of these drivers were above 25 years of age. Child pedestrians were mostly hit by cars but these children usually sustain severe injuries when involved in a collision with large vehicles compared to cycles. Relating to the day of week, child pedestrian mostly sustain severe injuries when involved in vehicle collision during weekend. Daytime and clear weather conditions accounted for approximately 63% of severe injuries associated with child pedestrians. Over 60% of the severe injuries associated with child pedestrian occurred on wider roads without median.

Table 1: Descriptive statistics of child pedestrian-vehicle crashes (2009 – 2016)

Variable	Frequency	Severe (%)	Non-severe (%)
Total	1449	63.01	36.99
Pedestrian Gender			
Male	707	66.76	33.24
Female	742	59.43	40.57
Pedestrian age			
≤ 12 years	952	67.44	32.56
13 to 17 years	497	54.53	45.47
Pedestrian action			
Crossing	1003	68.10	31.90
Other	446	51.57	48.43
Driver Gender			
Male	1330	64.21	35.79
Female	63	42.86	57.14
Driver age			
≤ 25 years	210	48.10	51.90
26 to 60 years	1443	66.32	33.68
> 60 years	21	66.67	33.33
Vehicle Type			
Car	774	64.65	35.35
Medium vehicle	330	66.97	33.03
Large vehicle	160	68.75	31.25
Cycle	205	45.37	54.63

Table 1: Continued

Variable	Frequency	Severe (%)	Non-severe (%)
Vehicle Manoeuvre			
Going ahead	1367	63.28	36.72
Others	60	53.33	46.67
Vehicle defects			
None	1305	62.84	37.16
Other	106	66.98	33.02
Day of week			
Weekday	1056	61.17	38.83
Weekend	393	67.94	32.06
Time			
AM Peak	316	64.87	35.13
Off Peak	551	60.62	39.38
PM Peak	582	64.26	35.74
Weather condition			
Clear	1336	62.80	37.20
Other	113	65.49	34.51
Light condition			
Day	1178	62.39	37.61
Night	271	65.68	27.27
Road description			
Straight and flat	1426	62.90	37.10
Other	22	72.73	27.27
Road surface type			
Tarred and good	1285	63.04	36.96
Tarred with potholes	121	65.29	34.71
Untarred	42	57.14	42.86
Road shoulder condition			
Good	481	65.07	34.93
Poor	150	68.00	32.00
No shoulder	817	60.95	39.05
Road separation			
Median	448	66.52	33.48
No median	999	61.56	38.44
Road width			
≤ 6m	32	46.88	53.13
> 6m	1063	63.31	36.69
Road surface condition			
Dry	1444	63.02	36.98
Wet	2	100.00	0.00
Location type			
Not at junction	1155	64.07	35.93
At junction	292	59.25	40.75
Traffic control			
None	803	64.26	35.74
Yes	644	61.65	38.35
Hit and run			
Not hit and run	1371	63.24	36.76
Hit and run	78	58.97	41.03

*Percentages for missing observations are not shown in the table.

3. Results and discussion

3.1. Results of logistic regression modelling

A binary logistic regression model was fitted to the set of independent variables to determine the possible factors contributing to the child pedestrian injury severity during vehicle collision. The estimated odds ratio associated with all the independent variables considered in the model and their corresponding 95% confidence interval are shown in Table 2. The *p*-value of the likelihood ratio test suggest that the fitted model is significantly different from the null model (model with only constant term) suggesting satisfactory (Table 2). The results from the model suggests that pedestrian's age, gender, location, driver's age and gender, day of week, time of day, light condition, vehicle type and road width were associated with injury severity among child pedestrians during crashes. Variables such as vehicle type, maneuver and defect, weather, location, traffic control, hit and run and road characteristics such as description, surface type, shoulder condition and road separation were omitted from the final model as a result of non-significance at 10% alpha level.

Table 2: Parameter estimates for logistic regression model

Variable	Coefficient	P-value	Odds ratio	95% CI (OR)
Pedestrian gender (*Ref: Male*)				
Female	-0.333	0.015	0.717	0.549, 0.936
Pedestrian age (*Ref: ≤ 12 years*)				
13-17 years	-0.332	0.025	0.717	0.536, 0.960
Pedestrian action (*Ref: Crossing*)				
Other	-0.623	0.000	0.536	0.398, 0.723
Driver gender (*Ref: Male*)				
Female	-1.016	0.002	0.362	0.190, 0.690
Driver age (*Ref: ≤ 25 years*)				
26-60 years	-0.488	0.003	1.801	1.222, 2.652
> 60 years	0.010	0.408	1.630	0.513, 5.179
Day of week (*Ref: Weekday*)				
Weekend	0.378	0.016	1.459	1.071, 1.986
Time of day (*Ref: Off peak*)				
AM peak	0.428	0.026	1.535	1.053, 2.238
PM peak	0.354	0.025	1.425	1.046, 1.942
Light condition (*Ref: Day*)				
Night	-0.544	0.006	0.581	0.394, 0.857
Vehicle type (*Ref: Cycle*)				
Car	0.782	0.000	2.185	1.428, 3.342
Medium vehicle	0.803	0.001	2.233	1.402, 3.556
Large vehicle	0.966	0.001	2.628	1.507, 4.581
Road width (*Ref: ≤ 6m*)				
> 6m	0.719	0.076	2.053	0.928, 4.541
Intercept	-0.208	0.145	0.498	0.195, 1.271
Goodness-of –fit Statistics				
Number of observations			1047	
AIC			1304.4	
Likelihood Ratio Test			p<0.001	

Although pedestrians have not been considered in the formulation of transportation and planning policies over the years (WHO 2013), they constitute the majority of road users with a higher risk of severe injuries during crashes. Children are the most defenceless road users and are more easily killed and seriously injured as a result of their limited prowess which endangers them on the road. School children especially, are at risk of being knocked down as they walk along the road to school and when crossing the road. Child pedestrians involved in vehicle-crashes in Ghana has increased in recent years and there is the need to protect child pedestrians. This analysis identified some of the risk factors associated with severe injuries to child pedestrians during crashes.

The study revealed that female child pedestrians were 28% less likely to be severely injured in crashes as compared to male children. This confirms the findings in the existing studies (Dhillon et al. 2001, DiMaggio and Durkin 2002) which concluded that males are more susceptible to severe injuries in crashes. This findings may be influenced by the fact that females focus on the dynamic attributes of the road whiles males focused only the mere attributes of the scene. Thus, male children have been seen as more prone to higher rates of pedestrian injuries than females (Zajac and Ivan 2003).

Pedestrian ages were found to influence their injury severity in the event of vehicle crash. Child pedestrians aged 13-17 years were 28% less likely to be severely injured as compared to children aged 12 years and below. Findings by Dhillon et al. (2001) also suggest that pedestrians aged between 5-9 years were more prone to severe injuries in crashes whiles DiMaggio and Durkin (2002) reached a similar conclusion for a larger age bracket of children from age 6-14.

Children walking along the road, edge or footpaths were 46% less likely to be severely injured as compared to children crossing the road at the time of the crash. As compared to pedestrians walking along the road, Sakar et al. (2011) observed greater risk of fatality for pedestrians crossing the road.

Examining the risk associated with child pedestrian due to drivers gender, the study revealed that female drivers were 64% less likely to cause severe injuries to child pedestrians as compared to males, a finding consistent with Kim et al. (2017). This could be attributed to the fact that female drivers are more careful as compared to male drivers thus are less likely to severely injure child pedestrians in the event of crash. In addition, male drivers are more likely to engage in risky driving behaviours such as excessive speeding, drink driving, and texting and such behaviour is likely to influence their collision involving children.

Driver age was shown to be an important factor that influences child pedestrian injury. Comparing with drivers below 26 years, child pedestrians were 80% less likely to be severely injured by drivers aged 26-60 years. This result may be influenced by the fact that drivers below 26 are inexperienced hence a higher tendency to cause severe injuries to child pedestrians. Conversely, compared to drivers below 26 years, child pedestrians were 63% more likely to be severely injured by drivers above 60 years. However, this result was not statistically significant at 10% alpha level.

The results of the fitted model showed that child pedestrians were 46% more likely to be severely injured when involved in vehicle collision on weekends than on weekdays. This result could be explain by the fact that on weekdays drivers are less likely to speed on the road due to traffic congestions. Contrarily, on weekends there are few cars on the road and less traffic congestion thus making road users carefree as there are usually no police officers around to sanction offenders. The findings support the conclusions in the existing literature (DiMaggio and Durkin 2002, Nance et al. 2004, Jang et al. 2013).

In comparison to the off peak period (all other times), child pedestrians were 54% more likely to be injured during the AM peak (6:30-9:30am) and 43% more likely to be injured during the PM peak (3:00-7:00pm). This may be influenced by the fact children go to school during the AM peak period and return home from school during the PM peak thus leading to the likelihood of being involved in vehicle-crashes resulting in severe injuries during these periods. It is unlikely to find children on the streets during the off peak periods. Islam and Jones (2014) found that severe crashes occurred more between the hours of 3:00-5:59pm. In a related study by Nance et al. (2004) it was reported that, 50% of all injuries occurred in the late afternoon/evening (3:00pm-7:00 pm).

The results of the study revealed that child pedestrians involved in night time crashes was 42% less likely to be severely injured compared to daytime crashes. This is because children are mostly engaged during the day and are usually not out at night hence there is high tendency for severe injuries in the day time as they move to and from school. This corroborates similar findings by DiMaggio and Durkin (2002) that, younger children are more likely to be struck down during daylight whiles adolescents were more likely to be struck down at night times.

The influence of vehicle type on the injury severity of child pedestrian was significant and larger vehicles were associated with more likelihood of severe injury. Comparing with cycles, child pedestrians were 119% and 123% more likely to be severely injured by cars and medium vehicles, respectively. Large vehicles posed greater risk of injury to child pedestrians as they were 163% more likely to cause severe injuries to child pedestrians as compared to cycles. This confirms the findings in the existing study that pedestrians hit by larger vehicle such buses are more likely to sustain fatal injuries (Abay 2013). Intuitively, larger vehicles have larger mass and thus can have higher impact on the body (Jang et al. 2013, Haleem et al. 2015). A number of studies have concluded that the type of vehicle is significant in determining injury severity (Sohn and Shin 2001, Zajac and Ivan 2003, Chang and Wang 2006, Kim et al. 2017).

Road width influences the extent of injury severity to child pedestrian involved in crashes. Wider roads increase the likelihood of severe injury to child pedestrians by 105% compared to narrow roads. The result is logical in the sense that children are exposed to more vehicles on a wider road and may not be able to cross as fast as they ought to. The results confirms the conclusions in existing studies that, injury severity increases with an increase in roadway width (Sohn and Shin 2001, Zajac and Ivan 2003, Eluru et al. 2008, Kim et al. 2017).

4. Conclusions

Using road traffic crashes data spanning over a 7 year period, this study explored the risk factors associated with child pedestrian injury severity when involved in a crash. Based on the logistic regression model developed, it was found that the probability of severe injuries to child pedestrians in the event of crash was significantly influenced by child gender, age and crossing behaviour. In addition, driver's gender, age, time of day, day of week, vehicle type and road width were also found to be contributing factors. The results confirm earlier conceptual arguments and findings. Identification of these factors and their relative impact on child pedestrian-vehicular injury severity provides information for policy formulation and guides the implementation of road and infrastructural policies to ensure that child pedestrians are much safer on the road.

To tackle child-related factors associated with injury severity, parents and guardians need to take personal responsibilities in providing the needed support to their children pertaining to road crossing or walking. Government and stakeholders should support the ongoing nationwide lollipop project to reduce road crashes and the scope of the project should be expanded to include a wider range of roads across the country. There is the need to educate drivers on road safety rules and regulations. That is, the Driver and Vehicle Licensing Authority (DVLA) should periodically provide refresher courses for drivers so that they are mindful of traffic rules and regulations. The law must be enforced and stiffer punishments should be meted out to road traffic offenders. Traffic lights are meant to organize the flow of traffic thus, the Department of Urban Roads must ensure that all traffic lights are functioning well and if for any reason the traffic lights are not working, traffic wardens should be at post to manage traffic to allow safer crossing for child pedestrian. It is recommended that there should be more visible road signs to alert drivers and pedestrian and the National Road Safety Commission must lead in this regard.

It is apparent that child pedestrian vehicular crashes is on the increase and is a cause for great concern for all stakeholders. Child pedestrian safety offers opportunities for future research as stakeholders search for new and improved methods to ensure pedestrian safety on our roads. This study was designed for one out of ten regions in Ghana. Nevertheless, this study brings to bare an initial understanding for the Ghanaian community of researchers and experts, on the risk factors associated with severe injuries to child pedestrians during collisions. The scope of child pedestrian safety on our roads can be expanded to include other regions for a bigger population size and consider travel speed for more balanced results in future research.

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