SPATIOTEMPORAL PATTERN AND DETERMINANTS OF CHILDHOOD ROAD TRAFFIC MORBIDITY AND MORTALITY IN NIGERIA: 2013- 2017

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ABSTRACT

This study examined the spatiotemporal pattern of road traffic crash morbidity and mortality in Nigeria among children below 18 years for the period 2013 to 2017. Data on road crashes, number of registered motor vehicles and motorcycles were obtained from the Federal Road Safety Corps' annual reports. Injury and mortality rates were standardized by the population of children and number of registered motor vehicles and motorcycles, to enable comparison between states. Global and local spatial autocorrelation of population and registered motor vehicles-based morbidity and mortality rates were analysed. Global Poisson and geographically weighted Poisson regression models were used to identify the determinants of morbidity and mortality for 2013. Morbidity and mortality decreased by 22 per cent and 26 per cent respectively. High morbidity and mortality were recorded in the North Central and North Western zones. Population-based injury and fatality rates clustered nationally with significance of p<0.05. Locally, injury and fatality rate 'hot spots' clustered in five North Central states. Determinants of mortality and morbidity are population below 18 years and number of registered motorcycles. Road improvement, traffic calming and management measures, and enforcement of the use of seat restraints, seat belts and helmets by children particularly in high-risk areas are necessary and therefore recommended.

JEL classification: R4

1. Introduction

Road traffic crashes (RTCs) are a major cause of death, injury and disabilities globally (WHO, 2018). In 2016, 1.35 million people were killed and up to 50 million injured or disabled due to RTCs worldwide (WHO, 2018). Although progress has been made to reduce road traffic deaths over the years in developed countries such as Sweden, UK, and Belgium (International Transport Forum-ITF, 2017), it is still very high in sub-Saharan Africa (SSA).

Globally, about 186,300 children under 18 years die from RTCs annually and 35.2% of these deaths occur in SSA (Lee, Nam & Abdel-Aty, 2018; WHO, 2015a). The global burden of road traffic childhood deaths is borne mainly in low-and middle-income countries where 93% of these deaths occur. In 2010, RTCs were the 8th leading cause of death among children 1-4 years old and the 4th among children 5-14 years in SSA. Road traffic crashes were the 9th leading cause of healthy life years lost among children in SSA. Although progress has been made in the prevention and control of infectious diseases among children in Africa, RTCs have been ignored in the childhood global health agenda (Bhalla et al., 2014).

1.1 Statement of the Problem

Road traffic crashes (RTCs) are a major public health challenge in Nigeria. The country recorded the second highest number (5,053) of road traffic deaths in SSA in 2016. Based on a modelled number of traffic deaths, Nigeria ranked 5th globally with a total of 39,802 deaths in 2016 (WHO, 2018). In 2004, the road traffic death rate among children in Nigeria was over 15.0 per 100,000 population (Peden et al., 2008).

RTCs affect children and their families in several ways. The educational development and the social development of children who are disabled and impaired are impeded due to long absence from school. Injuries and disabilities in children exacerbate poverty in families due to payments for medical care, legal costs, vehicle repair costs, loss of income for parents who leave their jobs to care for the child and rehabilitation costs. Children involved in RTCs also suffer psychosocial problems during and immediately after the crash (Gilles et al., 2003).

Previous studies on road traffic crashes involving children have examined the spatiotemporal pattern of traffic deaths and injury rates (Fridman et al., 2018), age, gender and type of victim (Ackaah, 2010; Rahman et al., 2016; Vu & Nguyen, 2018). According to Peden et al., (2008), factors that increase the risk of traffic injuries among children are child-related (small stature of children, poor interpretation of visual signals, risk-taking behaviour of adolescents, lack of adult supervision, income, gender, non-use of child restraints, helmets and seat belts) and environment-related (high traffic volume, mixed land use, lack of pavements for pedestrians, roads that encourage high vehicle speed, and lack of safe public transport systems). Effective interventions that reduce child crashes and injuries include use of exclusive lanes for motorcycles and bicycles (Radin et al., 2000), use of child restraints and helmets (Elliott et al., 2006) and supervision by adults (Damashek & Kuhn, 2013). Very few of these studies analysed the spatiotemporal pattern, characteristics and determinants of childhood traffic crash morbidity and mortality in SSA.

Studies on road crashes in Nigeria have focused mainly on the spatial pattern of traffic crashes and casualities (Akinyemi, 2019; Ipingbemi, 2008) and the characteristics of paediatric victims of RTCs presented in hospitals (Osifo et al., 2012; Hyginus et al., 2015). Most of the roads in Nigeria are characterized by cracks, potholes, and deformations which increase the risk and severity of road crashes (Aghamelu & Okogbue, 2011; Li et al., 2013; Lee et al., 2015). Spatial distribution of children injured and killed in road crashes have not been studied so far although 52.4% of the national population were aged 0-19 in 2006 (NBS, 2012). Hence, children constitute a high percentage of road users on roads. Children use roads as pedestrians, bicyclists, motorcyclists, hawkers and occupants of vehicles, so they are exposed to traffic injuries due to their limited physical and cognitive development, poor road infrastructure, risky driving behaviour, poor enforcement of alcohol laws and speed limits in Nigeria. Also, in densely-populated urban centres in northern Nigeria, a high number of children walk along roads begging for alms and food (Sambo, 2017; Makama et al., 2016). This predisposes them to road crashes. Risky driving behaviour by child motorcyclists such as driving at high speed, drink driving and and non-use of helmets expose children to crashes (Oginni et al., 2007; Nasir et al., 2011). Therefore, understanding the nature and determinants of the spatial variation of childhood crash morbidity and mortality is essential if Nigeria is to achieve significant reduction in childhood traffic injuries.

1.2 Objectives of the study

The objectives of this study therefore are to: 1) examine the spatiotemporal pattern of road traffic morbidity and mortality among children less than 18 years in Nigeria during the period 2013-2017 and 2) identify for the year 2013 the socio-economic and road infrastructure variables associated with the spatial variation of morbidity and mortality.

1.3 Significance of the study

Given the limited human and financial resources available for the implementation of traffic surveillance on roads across the country, an analysis of the spatiotemporal pattern of childhood road crashes, morbidity and mortality is relevant for identifying high-risk areas. This will aid the implementation of targeted crash reduction interventions and the provision of emergency medical facilities in target areas. Therefore, this study is important to policymakers, road traffic management agencies and public health workers.

2. Methods

2.1 Data collection technique

The analysis of the spatiotemporal pattern of road traffic morbidity and mortality among children below 18 years covered the 36 states and the Federal Capital Territory (Abuja) for the period 2013 to 2017. Projected population data from the 2017 Demographic Statistics Bulletin published by the National Bureau of Statistics (2018) were used. Data on the number and gender of children injured and killed in road crashes, number of registered motor vehicles and motorcycles were obtained from the Federal Road Safety Corps (FRSC) annual reports (2013-2017). However, details about the type of vehicle, nature of crash, and the number of minor, serious and fatal crashes involving adults and children were aggregated in the reports.

Road safety data are collected at the scene of a crash by road safety personnel using hand-held tablets. The data collection process is digitized and the data is sent directly to the FRSC data portal. Crash data from other agencies such as vehicle inspection offices, the Police, state traffic agencies and hospitals are also forwarded to the portal. The portal sifts the data to avoid multiple entries. Harmonization of the data is supervised by the National Committee on

Crash Information System (International Transport Forum-ITF, 2017). Crashes are however under-reported in locations where FRSC and Police patrol teams are absent. Hence, the actual number of road fatalities could be seven times higher than the figures reported by the FRSC (WHO, 2015b).

In this study, injury and mortality rates were standardized by total resident children population and total number of registered motor vehicles and motorcycles in order to allow comparisons between states similar to the procedure in Lassarre and Thomas (2005), and Erdogan (2009). Furthermore, average rates were calculated by dividing the sum of the rates for the years 2013-2017 by five.

2.2 Statistical techniques adopted

The presence and nature of spatial autocorrelation (dependency) of morbidity and mortality rates were assessed using global Moran's I statistic (Anselin, 1988). Similar to Erdogan (2009), the injury and mortality rates were aggregated for the entire five-year period to provide stability in the state level data. Moran's I tests, the null hypothesis that values at one location are independent of values at other locations (that is, traffic mortality and morbidity are randomly dispersed). Moran's I values vary from -1 to 1. Positive values indicate a clustered pattern, zero means randomness and negative values indicate a dispersed pattern. A statistically significant Moran's I ($p < 0.05$) leads to rejection of the null hypothesis and indicates the presence of spatial autocorrelation. Global Moran's I is computed as follows:

$$I = \frac{N \Sigma_i \Sigma_j w_{ij} (Xi - \bar{X})(Xj - \bar{X})}{(\Sigma_i \Sigma_j w_{ij}) \Sigma i (X_i - \bar{X})^2}$$

where:

- N = number of districts,
- Xi = value for a specific district,
- Xj = value for a neighbouring district,
- wij = element of a row-standardized weight spatial matrix (values of a row sum to 1) corresponding to the observation pair *i* and *j*.

Anselin local Moran's I was used to detect core cluster/outlier states with extreme morbidity and mortality unexplained by random variation and to classify them into hot spots (high values next to high), cold spots (low values next to low) and outliers (low among high and vice versa). Local Moran's I tests the hypothesis of the absence of spatial dependence when its expected value is -1/(N-1). ArcGIS 10.4.1 software was used to map and analyse the spatial patterns of morbidity and mortality rates. The data was integrated into the Geographic Information System (GIS) environment and converted into a projected coordinate system (UTM3IN WGS 84) for better analysis.

Generalized linear models have been used in studies relating to traffic safety for which the distribution of crashes count follows a Poisson or NB distribution (Washington et al., 2010). However, these models do not allow variation in association between geographic locations. Global models assume that processes accounting for crashes are spatially stationary across the study area. This could lead to biased results, and information on local variation may be important for policy makers (Cheng et al., 2011). Geographically-weighted Poisson regression (GWPR) investigates the extent to which processes might vary over space and allows a combination of geographically varying and constant parameters in a model. Conventional global Poisson regression model (GPR) is defined as:

$$O_i \sim \text{Poisson} \left(E_i \exp \left(\sum_k \beta_k x_{k,i} \right) \right) \tag{1}$$

where: x_{ki} is kth explanatory variable in place i and the β_ks are parameters and Poisson (λ) indicates a Poisson distribution with mean λ.

When parameter values vary with location (u_{xi} u_{yi}) which is the geographic coordinates of the centroid of the ith district (the location of i), the Poisson model in equation 1 is rewritten as:

$$O_i \sim \text{Poisson} \left(E_i \exp \left(\sum_k \beta_k (u_i, v_i) x_{ki} \right) \right) \tag{2}$$

where O_i, x_{ki}, and E_i denote the dependent variables. The coefficients $\beta_k(u_i, v_i)$ are assumed to be smoothly varying conditional on their location. Smoothed geographical variations of parameters in the model are estimated with a spatial weighting kernel. Nearby observations are weighted more heavily than more distant ones. The weighting kernel could be Gaussian or Bisquare. In this study, the corrected Akaike information criterion (AICc) was used to determine the weighting function, bandwidth size and the best model. The model with the smallest AICc was selected as the optimal model. A correlation matrix was produced among the independent variables to prevent multicollinearity in the model. The software GWR version 4.0.80 was used to implement GWPR.

3. Results

3.1 Temporal and spatial distribution of children morbidity and mortality at national and regional scales (Objective 1)

Data from the FRSC indicate that during the period 2013-2017, a total of 9,898 children were injured, while 2,038 were killed in 52,647 crashes. The number of children injured decreased from 2,379 in 2013 to 1,855 in 2016 followed by a slight increase to 1,864 in 2017. Fatalities declined from 500 in 2013 to 357 in 2016 followed by a rise to 370 in 2017. Generally, childhood road traffic morbidity and mortality decreased by 22% and 26% respectively. However, this decline was not uniform across the states. Morbidity increased in 17 states particularly in Bauchi (392%), Jigawa (1000%) and Katsina (97%) while mortality increased in 14 states, especially in Bauchi (92%), Ebonyi (1100%) and Jigawa (500%). Morbidity and mortality declined by over 75% in Kebbi and Delta states. In terms of gender variation, 61% (6032) of children injured were male while 39% (3866) were female. For fatalities, 59% (1201) were male while 41 (837) were female.

The spatial distribution of childhood road traffic mortality presented in figure 1 indicates that Kaduna State recorded the highest (11.9%) deaths while Abia State had the lowest (0.3%). Kaduna State (10.2%) had the highest morbidity (figure 1) while Borno State recorded the least (0.1%). Equal interval classification method was used to classify the states because of its unbiased selection of category and its capability of showing the values that are over- or under-represented.

Generally, 38% and 34% of the total morbidity and mortality occurred in the North Central zone, mainly in Kaduna State. The North West zone accounted for 19% and 17% of total morbidity and mortality respectively, with Kano State recording most of the cases in the zone. The South West zone accounted for 17% of total morbidity and 18% of total mortality. Most of the injuries occurred in Osun State, while fatalities were mainly in Oyo State.

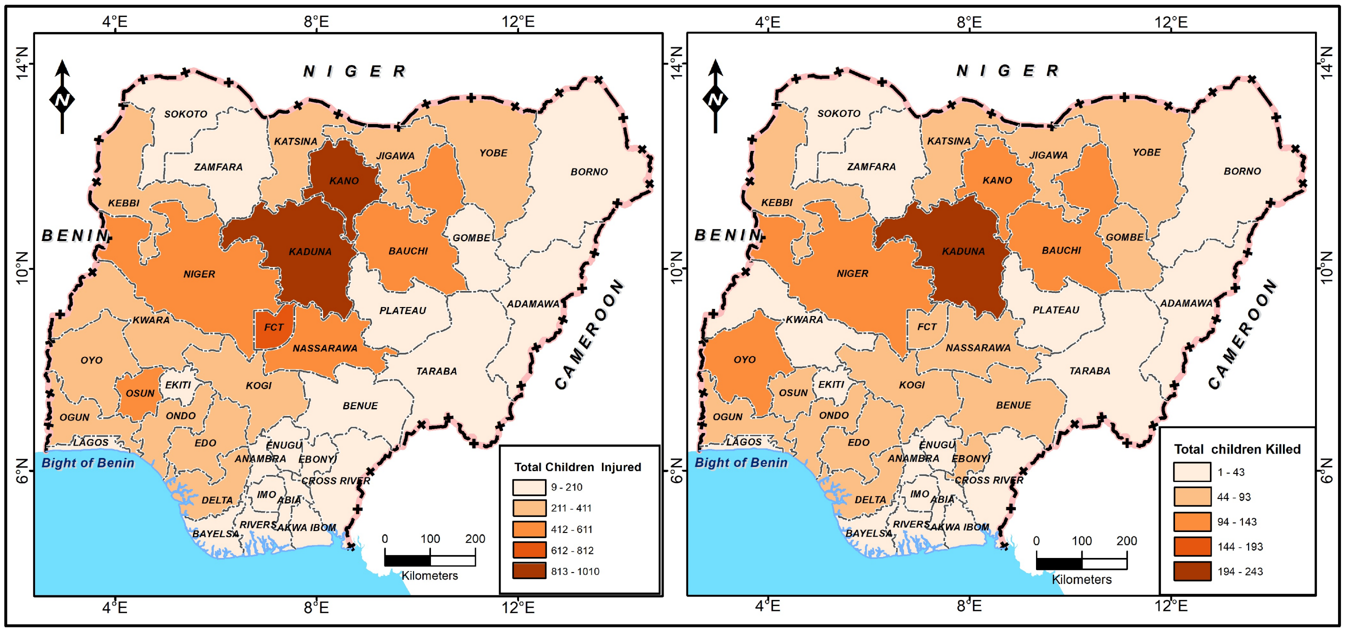

Figure 1. Distribution of childhood road traffic morbidity and mortality in Nigeria, 2013-2017

Source: Federal Road Safety Corps annual reports 2013-2018.

Population-based injury rate declined from 2.8 per 100,000 population in 2013 to 1.9 in 2017, while vehicle-based injury rate increased gradually from 190.9 per 100,000 in 2013 to 644.2 in 2017. Generally, between 2013 and 2017, population-based injury rate was 10.9 per 100,000 while vehicle-based injury rate was 1667.6. Population-based mortality rate decreased from 1.2 per 100,000 population in 2013 to 0.4 in 2017.

Furthermore, vehicle-based mortality rate increased gradually from 40.1 per 100,000 in 2013 to 127.9 per 100,000 in 2017. Over the five-year period, the population-based mortality rate in Nigeria was 2.9 per 100,000 population while the vehicle-based mortality rate was 337.3 per 100,000 vehicles. The average population-based injury rate was highest in Nassarawa (8.8 per 100, 000) and Abuja (8.8 per 100,000) while Akwa Ibom (0.1 per 100,000) and Borno (0.1 per 100,000) had the lowest rate (table 1). The highest average vehicle-based injury rate was recorded in Kaduna State (3400.9 per 100,000) while Lagos State had the lowest rate (35.2 per 100,000).

The average population-based mortality rate was highest (0.9 per 100,000) in the Federal Capital Territory (FCT) while Yobe State had the highest (994.7) vehicle-based mortality rate. Rivers State had the lowest mortality rate with 0.0 per 100,000 population and Lagos State with 9.1 per 100,000 vehicles.

As shown in figure 2, population-based injury rates between 2013 and 2017 ranged from 0.3 to 44.1 per 100,000. Injury rate was highest (44.1 per 100,000) in Nassarawa State followed by Abuja (44.0). It was very low in Borno (0.1) and Akwa Ibom (0.1) states. Injury rate based on registered vehicles (figure 3) ranged from 175.9 per 100,000 in Lagos State to 23,640.4 in Yobe State. Other states with high injury rates include Kaduna (17,004.3), Osun (16,748.4), Bauchi (14,473.3) and Nassarawa (14,470.2).

Nassarawa State had the highest (6.7 per 100,000) population-based mortality rate followed by Yobe (5.7). The lowest mortality rate was recorded in Rivers (0.2) State. However, Yobe State recorded the highest (4973.6 per 100,000) vehicle-based mortality rate. This was followed by Osun (4058.8) State while Lagos State had the lowest (45.6) rate.

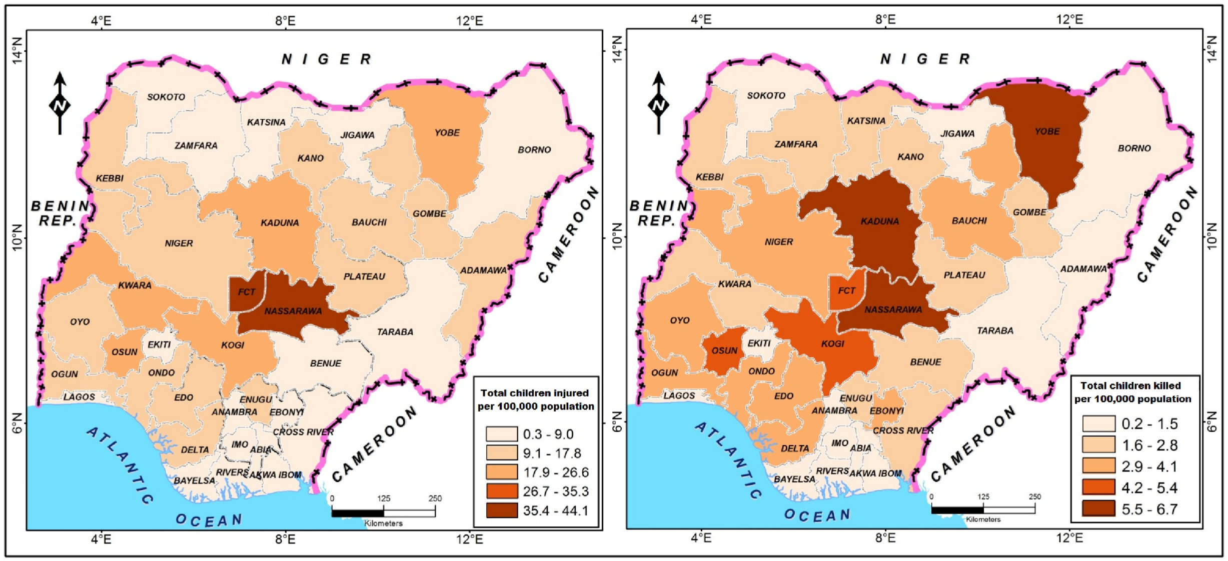

Figure 2. Distribution of childhood crash population- based injury and mortality rate, 2013-2017.

Source: Authors analysis.

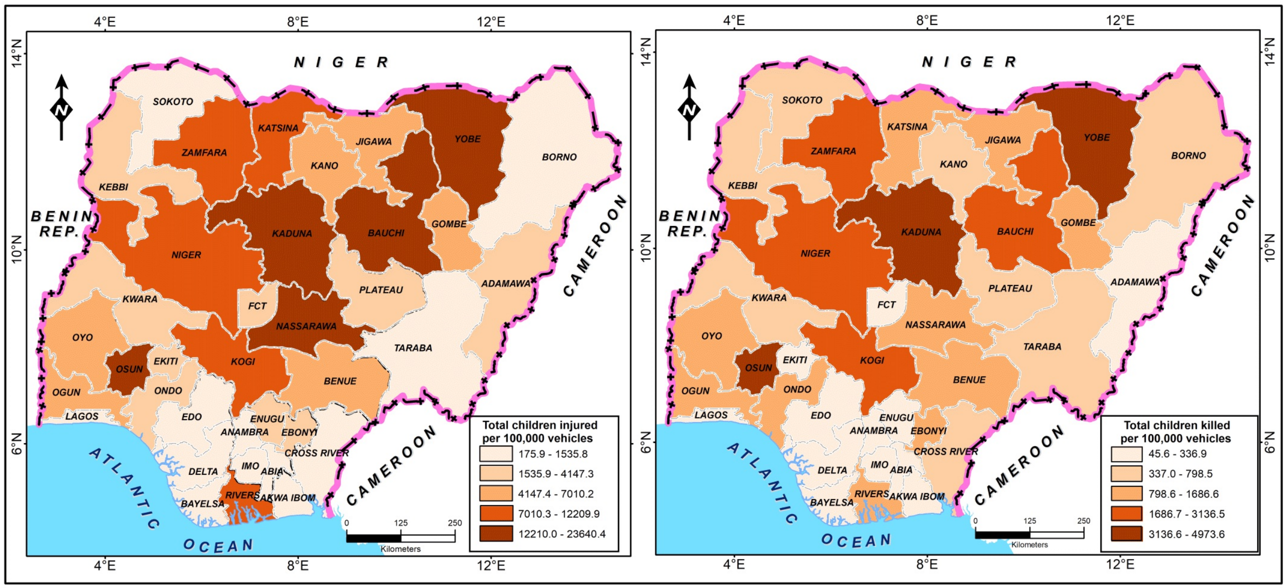

Figure 3. Distribution of childhood crash vehicles-based injury and mortality rate, 2013-2017.

Source: Author's analysis.

The results of the spatial analysis (table 2) showed the presence of positive spatial autocorrelation (clustered pattern) in population-based injury rate for each of the five years as well as the whole study period. Global Moran's I values (0.19-0.38) were significant ($p<0.05$) and higher than the expected values. The results of the global Moran's I analysis of vehicle-based injury rate indicated significant clustering pattern only in 2017 ($p<0.05$) while the Moran's I values for 2013, 2014, 2015 and 2016 and the whole study period were insignificant.

The spatial pattern of childhood population-based mortality rate was significantly ($p< 0.05$) clustered in 2013 (0.26), 2014 (0.19), 2017 (0.35) and 2013-2017 (0.38) while the random pattern in 2015 and 2016 were not significant ($p<0.05$). Although the global Moran's I values of vehicle-based mortality rate were positive and indicated random (2013, 2014 and 2015) and clustered (2016, 2017, 2013-2017) patterns, the values were not significant at $p<0.05$.

Anselin local Moran's I results showed that the FCT, Niger, Kaduna, and Nasasrawa states were significant high-high clusters of population-based injury rates while Imo, Rivers, Abia, and Akwa Ibom states were significant low-low clusters during the study period (2013-2017). Statistically significant low-high outliers were located in Plateau State. High vehicle-based injury rate districts clustered next to high ones in Katsina, Jigawa, Kano, Kaduna, and Bauchi states while only Abia State was a significant cold spot.

Furthermore, the FCT, Niger, Kaduna, Kogi and Nassarawa states were significant hot spot clusters of population-based mortality rates while Akwa Ibom, Rivers, Imo, Cross River and Abia states were significant cold spot locations between 2013 and 2017. Significant high-low outliers were located in Ekiti and Plateau states. Katsina, Jigawa and Bauchi were significant hot spot clusters of vehicle-based mortality rates. Rivers State was a significant high-low outlier district while Abuja and Kano states were significant low-high outlier districts.

Table 1. Childhood crash injury and mortality rates: 2013-2017

State	Population-based rates				Number of registered vehicle-based rates			
	Total Injury rate	Average annual injury rate	Total mortality rate	Average annual mortality rate	Total Injury rate	Average annual injury rate	Total mortality rate	Average annual mortality rate
Abia	6.9	1.4	0.4	0.1	1030.5	206.1	51.8	10.4
Adamawa	9.1	1.8	1.3	0.3	1969.1	393.8	293.7	58.7
Akwa Ibom	0.7	0.1	0.4	0.1	201.2	40.2	276.0	55.2
Anambra	5.7	1.1	1.1	0.2	567.3	113.5	132.1	26.4
Bauchi	15.0	3.0	2.8	0.6	14473.3	2894.7	2753.7	550.7
Bayelsa	4.2	0.8	1.3	0.3	717.0	143.4	286.6	57.3
Benue	7.1	1.4	2.2	0.4	4535.4	907.1	1160.6	232.1
Borno	0.3	0.1	0.3	0.1	667.0	133.4	618.0	123.6
Cross River	3.4	0.7	1.8	0.4	828.9	165.8	359.4	71.9
Delta	10.4	2.1	3.1	0.6	724.5	144.9	237.6	47.5
Ebonyi	5.9	1.2	3.2	0.6	2040.1	408.0	1160.3	232.1
Edo	12.4	2.5	3.0	0.6	1156.2	231.2	259.4	51.9
Ekiti	5.6	1.1	0.7	0.1	1823.7	364.7	277.6	55.5
Enugu	9.8	2.0	1.8	0.4	1998.6	399.7	336.9	67.4
Gombe	11.3	2.3	2.6	0.5	5410.1	1082.0	1274.3	254.9
Imo	4.9	1.0	1.1	0.2	792.0	158.4	167.3	33.5
Jigawa	6.7	1.3	1.4	0.3	7010.2	1402.0	1437.4	287.5
Kaduna	24.0	4.8	5.7	1.1	17004.4	3400.9	3952.1	790.4
Kano	11.7	2.3	1.7	0.3	5793.9	1158.8	798.5	159.7
Katsina	7.3	1.5	1.7	0.3	10303.0	2060.6	1617.2	323.4
Kebbi	9.8	2.0	2.4	0.5	3651.5	730.3	499.6	99.9
Kogi	23.7	4.7	4.3	0.9	8740.2	1748.0	2003.8	400.8
Kwara	21.3	4.3	2.1	0.4	3130.9	626.2	422.2	84.4

State	Population-based rates				Number of registered vehicle-based rates			
	Total Injury rate	Average annual injury rate	Total mortality rate	Average annual mortality rate	Total Injury rate	Average annual injury rate	Total mortality rate	Average annual mortality rate
Lagos	3.0	0.6	0.9	0.2	175.9	35.2	45.6	9.1
Nassarawa	44.1	8.8	6.7	1.3	14470.2	2894.0	1686.6	337.3
Niger	13.2	2.6	3.1	0.6	10365.8	2073.2	2661.7	532.3
Ogun	14.5	2.9	2.8	0.6	6572.1	1314.4	954.2	190.8
Ondo	14.7	2.9	3.6	0.7	4147.3	829.5	1432.1	286.4
Osun	21.3	4.3	4.3	0.9	16748.4	3349.7	4058.8	811.8
Oyo	11.9	2.4	3.0	0.6	6950.0	1390.0	983.9	196.8
Plateau	9.8	2.0	1.7	0.3	2658.7	531.7	396.1	79.2
Rivers	1.8	0.4	0.2	0.0	9162.4	1832.5	1422.0	284.4
Sokoto	2.2	0.4	0.7	0.1	1371.1	274.2	398.4	79.7
Taraba	4.6	0.9	0.9	0.2	1535.8	307.2	494.7	98.9
Yobe	20.4	4.1	5.7	1.1	23640.4	4728.1	4973.6	994.7
Zamfara	6.9	1.4	1.7	0.3	12209.9	2442.0	3136.5	627.3
FCT-Abuja	44.0	8.8	4.5	0.9	1959.572	391.9145	209.6702	41.93405
Total	10.9	2.2	2.9	0.6	1667.619	333.5237	337.2577	67.45154

Source: Author's analysis.

Table 2. Results of global spatial autocorrelation of childhood crash morbidity and mortality:2013-2017

		Morbidity					Mortality				
	Year	Z-Score	P-Value	Global Moran's Index	Expected Index	Interpretation of pattern	Z-Score	P-Value	Global Moran's Index	Expected Index	Interpretation of pattern
Population-based rate	2013	3.012817	0.002588	0.264556	- 0.027778	Clustered	2.153228	0.031301	0.182784	- 0.027778	Clustered
	2014	2.229011	0.025813	0.186471	- 0.027778	Clustered	2.198487	0.027914	0.187269	- 0.027778	Clustered
	2015	4.887104	0.000001	0.445683	- 0.027778	Clustered	1.128719	0.259016	0.085110	- 0.027778	Random
	2016	3.243063	0.001183	0.291133	- 0.027778	Clustered	0.820598	0.411875	0.054497	- 0.027778	Random
	2017	3.862058	0.000112	0.352362	- 0.027778	Clustered	1.801572	0.071613	0.071613	- 0.027778	Clustered
	2013-2017	4.222431	0.000024	0.379155	- 0.027778	Clustered	2.557769	0.010535	0.230079	- 0.027778	Clustered
Number of registered vehicle-based rate	2013	1.67944	0.093066	0.135363	- 0.027778	Clustered	0.343586	0.731158	-0.000715	- 0.027778	Random
	2014	0.487015	0.626248	0.018589	- 0.027778	Random	0.885978	0.375629	0.035274	- 0.027778	Random
	2015	-1.520219	0.128456	-0.15258	- 0.027778	Random	-1.575903	0.115048	-0.138881	- 0.027778	Random
	2016	1.612005	0.106961	0.109402	- 0.027778	Random	1.771995	0.076395	0.145828	- 0.027778	Clustered
	2017	3.047916	0.002304	0.277301	- 0.027778	Clustered	1.67044	0.094832	0.140475	- 0.027778	Clustered
	2013-2017	0.113626	0.156406	0.113626	- 0.027778	Random	0.779476	0.435699	0.049446	- 0.027778	Clustered

Source: Authors's analysis.

3.2 Determinants of the spatial variation of childhood morbidity and mortality (Objective 2)

Spatial autocorrelation in the explanatory variables was determined by estimating Moran's I statistics. The Moran's I values of some of the variables were higher than the expected I value, indicating that some of the variables were non-stationary. Before estimating the models, bivariate correlation among the independent variables was calculated to test for multicollinearity. The correlation coefficients were less than 0.9 suggesting the absence of multicollinearity.

The results of global model on morbidity (table 3) indicate that the variables road length, per capita income, population of children and registered motorcycles were significant at 95% confidence level. Variation of fatalities (table 4) was significantly influenced by per capita income, population of children, registered motorcycles, and number of vehicle licences. The global model on morbidity had AICc = 1413.898 and adjusted R^2= 0.38 while the model on mortality had AICc = 354.965 and adjusted R^2= 0.18.

The best GWPR model on morbidity (table 3) had AICc = 1411.729 and adjusted R^2 = 0.39 while the model on mortality had AICc = 354.745 and adjusted R^2 = 0.19. The difference in deviance between the global and GWPR model on morbidity and mortality were 2.219 and 2.935 respectively. The improvement of model performance was evident in the global and GWPR models for morbidity and mortality from the values of AICc, difference in deviance and adjusted R^2. In the two models, deviance explained was higher in GWPR models. Also, AICc values, and deviance were lower in GWPR models.

The results of the geographical variability test in the model for morbidity indicate that the difference of criterion using AICc was negative for the parameter estimates suggesting spatial variability, except for the variables registered cars and per capita income. Furthermore, difference of criterion of the parameter estimates of the variables length of roads, per capita income, and children population were negative, indicating spatial variability while other explanatory variables were stationary. The distribution of the t-values for the local model on morbidity and mortality indicate that the population of children and number of registered motorcycles had positive and significant effect on the number of children injured and killed in road crashes across the states at $p<0.05$ significance level. The parameters number of cars, vehicle licences, length of roads and per capita income had no significant influence on morbidity and mortality.

Table 3. Summary of global and GWPR model statistics on morbidity: 2013-2017

Global Poisson Regression					Geographically Weighted Poisson Regression Bi-square					
Coefficients	Estimates	Std. Error	Z value	Pr (> z)	Minimum	Lower Quartile	Median	Upper quartile	Maximum	Status
Intercept	3.091915	0.074395	41.561030	<0.00001	3.090982	3.091290	3.091550	3.092023	3.092565	Non-stationary
Road length	-0.000167	0.000052	-3.212847	0.000659	-0.000168	-0.000168	-0.000167	-0.000167	-0.00066	Non-stationary
Income	0.000000	0.000000	-3.529236	0.000209	0.0000000	0.000000	0.000000	0.0000000	0.000000	Stationary
Children population	0.000000	0.000000	27.235629	<0.00001	0.000000	0.000000	0.000000	0.0000000	0.000000	Non-stationary
Registered cars	0.000001	0.000001	1.152417	0.124578	0.000001	0.000001	0.000001	0.000001	0.000001	Stationary
Registered motorcycles	0.000030	0.000002	15.726266	<0.00001	0.000030	0.000030	0.000030	0.000030	0.000030	Non-stationary
Vehicle license	0.000002	0.000001	1.597357	0.055099	0.000002	0.000002	0.0000002	0.000002	0.000002	Non-stationary
Global AICc	1413.898	Percentage deviance explained= 0.38								
GWPR fixed Gaussian AICc	1413.356	Percentage deviance explained= 0.39								
GWPR fixed Bi-square AICc	1411.729	Percentage deviance explained = 0.39								

Source: Authors' analysis.

Table 4. Summary of global and GWPR model statistics on mortality:2013-2017

Global Poisson Regression					Geographically Weighted Poisson Regression Bi-square					
Coefficients	Estimates	Std. Error	Z value	Pr (> z)	Minimum	Lower Quartile	Median	Upper quartile	Maximum	Status
Intercept	1.650567	0.154788	10.663381	<0.00001	1.649389	1.649768	1.650198	1.650621	1.651496	Non-stationary
Road length	0.000158	0.000102	1.555904	0.059854	0.000157	0.000158	0.000159	0.000159	0.000159	Stationary
Income	0.000000	0.000000	-1.887925	0.02958	0.000000	0.000000	0.000000	0.000000	0.000000	Non-stationary
Children population	0.000000	0.000000	7.490671	<0.00001	0.000000	0.000000	0.000000	0.000000	0.000000	Non-stationary
Registered cars	-0.000001	0.000002	-0.629616	0.264675	-0.000001	-0.000001	-0.000001	-0.000001	-0.000001	Stationary
Registered motorcycles	0.000019	0.000005	4.230333	0.00012	0.000019	0.000019	0.000019	0.000019	0.000019	Non-stationary
Vehicle license	0.0000004	0.000003	1.376508	0.084411	0.000004	0.000004	0.000004	0.000004	0.000004	Non-stationary
Global AICc	354.96566	Percentage deviance explained= 0.18								
GWPR fixed Gaussian AICc	354.74554	Percentage deviance explained= 0.19								
GWPR fixed Bi-square AICc	354.865668	Percentage deviance explained= 0.19								

Source: Authors' analysis.

4. Discussion

In reference to the first objective, this study has provided an empirical analysis of the spatiotemporal variation of children RTC morbidity and mortality in Nigeria from 2013 to 2017. According to data from the FRSC, the number of children injured and those killed in road crashes decreased by 22% and 26% respectively during the period 2013-2017. Although the decline was not consistent in all states, it reflects the concerted efforts of the FRSC to reduce crashes on roads. Previous studies (Elliott et al., 2006) have shown that child restraints reduce the risk and severity of injuries and deaths.

Similar to findings by Fridman et al. (2018), population-based injury and mortality rates also declined during the study period. The majority of injured and dead victims were males, similar to results obtained in other middle- and low-income countries such as Ghana (Ackaah, 2010), Malaysia (Rahman et al., 2016) and Vietnam (Vu & Nguyen, 2018). This could be due to their exposure on roads and risk-taking behaviour.

This study found that the majority of the fatalities were recorded in Kaduna, Kano, Bauchi Niger, and Nassarawa states. In addition, injured children were mostly in Kaduna, Kano, Abuja, Nassarawa and Bauchi states. State-level variation in injury and mortality rates in 2013-2017 corroborate the variation in crash morbidity and mortality. Nassarawa, the FCT, Kaduna, Yobe and Osun states were determined as problematic with the injury and mortality rates standardized by population. Yobe, Kaduna, Osun, Bauchi and Nassarawa states were determined as problematic with the injury rate standardized by the number of registered motor vehicles. Although Lagos State had the highest registered vehicles (27%), the state recorded 3.7% of total crashes and had the lowest vehicle-based injury and mortality rates. This could be attributed to the enforcement of traffic regulations by the traffic management agency established in 2000. Yobe State which accounted for 0.4% of the total number of registered vehicles had the highest vehicle-based injury and mortality rate. The high injury and mortality rate could be due to drivers' behaviour, including driving at high speed, drink-driving, non-use of helmets and seat belts and the condition of vehicles.

Local Moran's I was used to analyse spatial association to identify locations of crash morbidity and mortality hot spots, cold spots and outliers. Niger, Kaduna, the FCT, and Nassarawa states were determined as hot spot clusters with population-standardized injury rates while Katsina, Jigawa, Kano, Kaduna and Bauchi states were determined as hot spot clusters of registered vehicle standardized injury rates. Katsina, Jigawa, and Bauchi states were significant hot spots of vehicle-based mortality rates while Niger, Kaduna, the FCT, Kogi and Nassarawa states were determined as hot spots using population standardized rates. Some of the hot spot states, such as Jigawa, recorded very high increase in morbidity and mortality in 2016-2017. Overall, hot spots of injury and mortality rates were located mainly in the North Central zone. This is expected since the North Central zone recorded the highest number of children injured and killed in road crashes. The North Central zone has a high population of children aged under 18 years. Sambo (2017) noted that a high number of out-of-school children between five and fifteen years in the North Central zone roam the highways and streets in search of alms and food. These child beggars, who number about seven million, are at high risk of road crashes. Makama et al. (2016) reported that 96% of child beggars interviewed in Zaria had experienced road crashes as pedestrians two or three times. Interestingly, cold spots of injury and mortality rates standardized by population and registered vehicles were determined consistently in the South South (Cross River, Akwa Ibom and Rivers states) and South East (Imo and Abia states) zones.

Most of the crashes in high-risk states were fatal and occurred on highways linking major commercial/densely populated cities and peri-urban settlements. According to FRSC reports, the majority of reported crashes, injuries and fatalities regularly occurred on Abuja-Lokoja, Abuja–Kubwa, Kaduna–Zaria, Abuja–Kaduna, Kano–Zaria, Nassarawa–Akwanga, Doka–Kaduna, Lagos–Ibadan, and Bauchi–Gombe highways. High traffic volume, poor road maintenance, lack of post-crash care and human factors contribute to crashes and casualties on these routes. Serious pavement failure in the form of cracks, potholes, deformations, and rutting were observed on major highways in the country (Aghamelu and Okogbue, 2011). Studies have shown that poor pavement condition increases the severity of crashes on high speed roads (Li et al., 2013; Lee et al., 2015).

In reference to the second objective of this study, global Poisson regression and GWPR analyses were adopted to analyse the determinants of the spatial distribution of childhood crash injury and fatalities. Output from global and local models indicated that GWPR models improved model fitting than the global models. Values of the AICc, deviance and adjusted R^2 indicated improvement in the model performance of GWPR models. Population of children and number of registered motorcycles had positive and strong influence on both morbidity and mortality. In broad terms, states such as Kaduna, Kano and Nassarawa with high populations of children, had high morbidity and mortality rates. In addition, Kano, Ogun, Delta, Nassarawa and Kaduna states with high number of registered motorcycles recorded high numbers of children injured and killed. The positive significant association between fatalities and number of registered motorcycles was due to the rise in the number of child motorcyclists, including drivers and passengers. The number of registered motorcycles has increased over time. Due to the fact that motorcycles can be manoeuvred through narrow paths during congestion, they have become attractive to passengers who live in densely populated cities and rural areas where there is limited or no public transport. Adolescents ride motorcycles for commercial purpose to earn income due to their poor socio-economic condition. Child motorcyclists drive aggressively, speed, drive under the influence of alcohol, use mobile phones while driving, do not wear helmets nor obey traffic regulations (Oginni et al., 2007; Nasir et al., 2011). Their reckless driving and non-use of helmets expose them to high risk of crashes and injuries.

4.1 Contribution to knowledge

Findings in this study have important implications for government, policymakers, public health workers, traffic and road safety agencies. Measures such as enforcement of speed limits, use of car restraints and helmets, and installation of traffic lights that will enhance the safety of children either as pedestrians or passengers need to be implemented, particularly in high-risk areas. Road infrastructure design can be improved to enhance child safety. For example, the provision of separate cycle lanes and pedestrian walkways, installation of traffic calming and management measures such as speed humps and rumble strips, improvement of visibility at junctions, and installation of traffic lights will reduce the risk of crashes for children. Enforcement of laws and regulations relating to the use of child restraints, seat belts, helmets and drink-driving need to be reinforced by road safety agencies. Educational and safety programmes are necessary for motorists, parents and children.

It must be considered however, that the present study has some limitations. Under-reporting of crash cases is high because the FRSC and the Police do not have the capacity to know about all crash cases. Also, since the FRSC only reports deaths that occur within 24 hours of a crash, deaths that occur after this period are not recorded. Due to the unavailability of data at the state level, childhood morbidity and mortality data by cause of crash, type of road user (pedestrian, vehicle passenger/driver and cyclist), weather conditions, police enforcement and time of crash could not be examined in this study. Trends and patterns within states were not examined in this study because explanatory variables were only available at the state level. Future research on the specific location of crashes on arterial and residential roads within states is warranted.

5. Conclusion

This study demonstrates that childhood road traffic morbidity and mortality are a public health challenge in Nigeria. Identification of safety-deficient states using GIS-aided spatial analysis is necessary for the implementation of targeted strategies that will reduce road crash morbidity and mortality among children. Although a declining trend was exhibited at the national level for the period 2013-2017, morbidity and mortality increased in 17 and 14 states respectively, particularly in Jigawa, Katsina, Bauchi, and Ebonyi states. The results reveal a significant spatial variation of children injured and killed in road crashes across districts. This study highlights the need for improvement of infrastructure design, implementation of traffic calming and management measures and enforcement of laws and regulations relating to the use of seat restraints, seat belts and helmets by children particularly in high-risk areas.

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