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ABSTRACT

Objectives: Each year, pedestrian injuries constitute over 40% of all road casualty deaths and up to 60% of all urban road casualty deaths in Ghana. This is as a result of the overwhelming dependence on walking as a mode of transport in an environment where there are high vehicular speeds and inadequate pedestrian facilities. The objectives of this research were to establish the (1) impact of traffic calming measures on vehicle speeds and (2) association between traffic calming measures and pedestrian injury severity in built-up areas in Ghana.

Method: Vehicle speeds were unobtrusively measured in 38 selected settlements, including 19 with traffic calming schemes and 19 without. The study design used in this research was a matched case-control. A regression analysis compared case and control casualties using a conditional logistic regression.

Results: Generally, the mean vehicle speeds and the proportion of vehicles exceeding the 50 km/h speed limit were significantly lower in settlements that have traffic calming measures compared to towns without any traffic calming measures. Additionally, the proportion of motorists who exceeded the speed limit was 30% or less in settlements that have traffic calming devices and the proportion who exceeded the speed limit was 60% or more in towns without any traffic calming measures. The odds of pedestrian fatality was significantly higher in settlements that have no traffic calming devices compared to those that have (odds ratio \( [OR] = 1.98; 95\% \text{ confidence interval, } 1.09–4.43\)). The protective effects of a traffic calming scheme that has a speed table was notably higher than those where there were no speed tables.

Conclusion: It was clearly evident that traffic calming devices reduce vehicular speeds and, thus, the incidence and severity of pedestrian injuries in built-up areas in Ghana. However, the fact that they are deployed on arterial roads is increasingly becoming a road safety concern. Given the emerging safety challenges associated with speed calming measures, we recommend that their use be restricted to residential streets but not on arterial roads. Long-term solutions for improving pedestrian safety proposed herein include bypassing settlements along the highways to reduce pedestrians’ exposure to traffic collisions and adopting a modern way of enforcement such as evidence-based laser monitoring in conjunction with a punishment regime that utilizes the demerit points system.

Background

Pedestrian injuries are a growing public health problem in low- and middle-income countries (LMICs). In Ghana, over 40% of all road injury casualties are pedestrians. High pedestrian injury rates have also been reported in many other LMICs. Crash statistics show that pedestrian fatalities constitute over 60% of all urban road user deaths in Ghana (Building & Road Research Institute 2016) and some other LMICs (Donroe et al. 2008; Khayesi 1997). Conversely, less than 15% of traffic crash victims are pedestrians in many high-income countries (HICs; Retting et al. 2003; World Health Organization 2009; Zhu et al. 2008).

The unfavorable disparities in pedestrian injury rates between LMICs and HICs have arisen largely because LMICs do not usually formulate appropriate rules to protect road users, particularly pedestrians and, when they do, enforcement is lacking. For instance, whereas pedestrian facilities like sidewalks and pedestrian paths and bridges are available and motorists yield to pedestrians at crosswalks in HICs, these facilities and practices are generally lacking in Ghana and many other LMICs. Therefore, pedestrians and fast-moving vehicles share the same road space to the detriment of pedestrians. In many African countries, over 80% of students walk to school (Koekemoer et al. 2017). In Ghana, road reservations in settlements have been encroached upon in many cities. Residents use these spaces mainly for roadside trading. Sometimes roadside hawking activities spread to the road shoulders, which in most cases are the only

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spaces available for pedestrians to walk on. Speeding is an important risk factor for pedestrian injuries. For example, the fatality risk for pedestrians increases by 4.5 times when the striking speed of a vehicle increases from 50 to 65 km/h (World Health Organization 2018). Nevertheless, speeding is pervasive in Ghana to the extent that over 90% of motorists exceed the posted speed limit (Damsere-Derry et al. 2008; Derry et al. 2007). Pedestrians are therefore exposed to road injuries. Between 2002 and 2006, for instance, police crash data showed that the probability of a pedestrian’s death being attributed to excessive speeding in Ghana was 65% (Damsere-Derry et al. 2010).

In HICs, multifaceted prevention techniques such as separating vulnerable road users including pedestrians from fast-moving vehicles by providing the requisite pedestrian infrastructure and enforcing traffic regulations using deterrent-based techniques have collectively worked to promote pedestrian safety in those countries. According to the deterrent theory, criminal behaviors (in this case, breaking speeding regulations) can be prevented by threatening potential offenders with punishment that outweighs any pleasure, reward, or gain associated with the criminal act (Robinson 2010). The deterrent theory has 3 main elements, namely, certainty, celerity, and severity. According to this theory, for any road safety countermeasure to work, motorists should perceive that the probability of being detected, apprehended, and punished is high (certainty of detection, apprehension, and punishment), in addition to the swiftness (celerity) of the punishment and severity of punishment. Evaluation of road safety interventions in the United States indicates that deterrence theory underpins the success of the speed limit law (Ritchey and Nicholson-Crotty 2011). The demerit point system is an example of a deterrence theory–based enforcement used in many HICs to discourage speeding. Under this system, each individual is given 10 to 30 points depending on the jurisdiction. When a motorist commits any traffic offense, points are deducted from his total points until the individual’s points are exhausted, at which point the driver’s license is suspended for a period of time. In Queensland, Australia, for example, when a motorist is caught traveling above the speed limit by less than 13 km/h, he is fined AUD 162 and loses 1 demerit point but will be fined AUD 1,137 and lose 8 demerit points when traveling more than 40 km/h above the speed limit (Queensland Government 2017). This punishment is for first-time offenders. Recidivism of the speeding behavior usually results in more severe punishment.

Conversely, in Ghana, road safety is not grounded in deterrence theory. This is largely because the police whose duty it is to initiate enforcement are alleged to have been compromised (Adu Gyamfi 2015; Starr FM 2015). Therefore, in an effort to combat speed-related pedestrian injuries in Ghana, various traffic calming devices have been installed in many towns and at hazardous road locations. Speed calmer devices such as bumps and humps force motorists to significantly reduce their speeds to avoid sudden vertical accelerations (Lav et al. 2017). The sections treated with traffic calming measures evaluated in this report include a combination of many speed reducing interventions, including speed limit signs, carriageway narrowing, roadline markings, rubberized delineators, studs, speed humps, speed tables, and speed bumps in settlements along arterial roads in Ghana. There are between 2 and 5 different types of traffic calming devices per location. The focus of this report is on speed tables, speed humps, and speed bumps, which have become the predominant speed calming measures in Ghana.

Evaluation of a few traffic calming devices in Ghana showed a significant decline in pedestrian injuries and severity (Afukaar 2003; Afukaar and Damsere-Derry 2010). The effectiveness of traffic calming devices has been reported elsewhere (Jones et al. 2005; Tester et al. 2004). According to Tester et al. (2004), installation of speed humps in residential neighborhoods in Oakland, California, reduced child pedestrian injuries by 53%. Elsewhere, these physical speed reducers are restricted to local and residential neighborhoods. However, in Ghana, their use is not limited to local streets; that are also used on arterial and trunk roads, which is increasingly becoming a road safety challenge.

The effectiveness of speed calming devices in reducing vehicular speeds and pedestrian injuries has been widely approved as the state-of-the-art traffic calming countermeasure in Ghana. This is largely due to the ineffective enforcement of the speed laws in Ghana by the police. Residents are increasingly demanding that traffic calming devices be installed in their towns. During run-ups to elections, slogans such as “No speed humps, No votes” are posted on bill boards as communities appeal to road authorities (politicians) for traffic calming devices. When their demands for traffic calming devices are not forthcoming, resulting in pedestrian accidents, residents take the law into their own hands and build “illegal” speed calming measures (Ultimate FM 2018). The caveat of using illegal speed calming devices is that they can cause pavement distress (Abdel-Wahed and Hashim 2017; Bekheet 2014) as well as trigger spinal injury and road accident injuries or death (Kodjo 2016; Myjoyonline.com 2016). In particular, community-built speed calmer devices pose mobility and safety problems.

This article evaluates the effectiveness of speed calming devices and recommends alternatives as well as long-term speed control measures to improve pedestrian injury prevention strategies.

Objectives

The objectives of this study are to establish the (1) impact of traffic calming measures on vehicle speeds and (2) association between traffic calming measures and pedestrian injury severity in built-up areas in Ghana.

Methodology

Data sources

This research used 2 main sources of data, primary and secondary. The primary data were vehicle speed data obtained from the field. Vehicle speeds were obtained on 11,329 vehicles in 38 settlements located across the country. A
radar speed gun was used to unobtrusively measure vehicle speeds in a snapshot fashion. At each location, vehicle speeds were measured for 2 h on roads with high traffic volumes and for 3 h on low-volume roads. The method for speed measurement was described in detail in an earlier report (Derry et al. 2007).

The secondary data used in this article were obtained from the Building & Road Research Institute’s accident data bank. These data are collated from police accident reports. As in many such data sets, there is some underreporting (Salifu and Ackaah 2012). Accidents resulting in severe injuries or fatalities are less likely to be underreported, however. Classification of road injury severity is based on a 30-day time frame. For instance, if an accident victim dies within 30 days of a collision or is hospitalized for at least 24 h within 30 days after a road crash, the injury severity is classified as a fatality or injuries requiring hospitalization, respectively.

**Site selection**

We conducted a matched case-control study using 38 small-medium settlements situated on selected trunk roads in Ghana. Nineteen of the settlements had some traffic calming measures and the other 19 had no traffic calming measures. The mean number of inhabitants per location was about 4,800; populations varied from a low of 211 inhabitants at Akrade on the Tema–Akosombo highway to a high of about 27,000 at Odumase (Konongo) on the Accra–Kumasi Highway. The best method for measuring pedestrian exposure is traffic volume. However, these data are currently unavailable in Ghana. Each settlement had a speed limit of 50 km/h. The highways investigated were major arterial roads in Ghana, namely, national (N), interregional (IR), and regional (R) highways (roads), which are predominantly single carriageways. Although in most cases there were no perfect matches among settlements, attempts were made to find settlements with comparable populations. Settlements with a population difference of less than 1,000 residents were assumed to have comparable exposure. In essence, efforts were made in the field to pair towns that have traffic calming measures with settlements without these interventions based on population. Case casualties were injured pedestrians in settlements with speed calming devices and controls were casualties found in settlements with no traffic calming devices.

**Analysis**

After field data collection, frequency matching with respect to age and gender of the pedestrian casualties was carried out. Because the traffic calming measures were installed at different times at different locations, traffic crash data for the same time periods were retrieved and used. All settlements had a speed limit of 50 km/h.

Injury severity was the dependent variable in the analysis. This variable was binary; that is, fatal versus nonfatal. Having a traffic calming measure or not in settlements was our principal predictor variable, which was also dichotomous. We used traffic crash data from the Building & Road Research Institute’s (2016) data bank with the guidance of strip maps in such a manner that pedestrian injuries for road sections on the arterial roads of each settlement were delineated from other sections of the road. Other covariates studied included time of day of the crash, age and gender of traffic injury casualties, and mean vehicle speeds in the settlements.

The numerical variables among the covariates were casualty age (discrete) and vehicle speeds (continuous), which were stratified into 3 and 2 levels, respectively. Classification of age was as follows: children (0–17 years), active adult population (reference; 18–59 years), and elderly (60 years or older). Similarly, prevailing mean vehicle speeds were dichotomized as speeds up to 50 km/h (reference) and mean speed greater than 50 km/h for comparison.

**Logistic regression model**

Statistical analyses were conducted using STATA (Windows Version 13). We used standard logistic regression (SLR) analyses to obtain the unadjusted odds ratios (ORs) and a multivariable conditional logistic regression to estimate the adjusted ORs.

The logistic regression function describing the logistic model is in the form

\[
 f(z) = \frac{1}{1 + e^{-z}}. \tag{1}
\]

The conditional logistic model for matched analysis is given as

\[
 \log itP(X) = \alpha + \beta E + \sum \gamma_1 V_{1i} + \sum \gamma_2 V_{2i} + E \sum \delta_j W_j, \tag{2}
\]

where \( \alpha \) is a constant, \( E \) is the exposure variable (status of traffic calming devices), \( \beta \) is the coefficient of the exposure variable, \( \gamma_j \) are coefficients of the dummy variables, \( W_j \) denotes potential confounders, \( \gamma_{2j} \) are the coefficients of the potential confounders not involved in the matching, and \( \delta_j \) are the coefficients of the product interaction variables if present (Kleinbaum and Klein 2010).

**Study period**

The vehicle speeds were measured in 2011. Six-year accident data (i.e., 2006–2011) for the settlements were obtained and analyzed.

**Ethical approval**

The study used a publicly available data set from the Building & Road Research Institute (2016) without any identifiers and was therefore exempted from ethical approval reviews by the Committee on Human Research and Ethics of the Kwame Nkrumah University of Science & Technology.
Results

**Distribution of vehicle speeds**

Free-flowing speeds were measured with a speed gun on 11,329 vehicles in built-up areas and the results are displayed in Table 1. Typically, the mean speeds in settlements and the proportion of vehicles exceeding the speed limit were considerably lower in settlements with traffic calming devices compared to locations without any traffic calming schemes. For example, among settlements that have traffic calming devices, the observed mean speeds were most often less than the posted speed limit of 50 km/h: Kubease, 43 km/h; Anyinam, 41 km/h; Bokro, 43 km/h; and Kpong, 37 km/h. There were, however, a small number of settlements that have traffic calming schemes and yet recorded mean vehicle speeds were far greater than the posted speed of 50 km/h: Kikam, 63 km/h; Bechem, 66 km/h; Anomabu, 68 km/h; and Biriwa, 75 km/h. It was evident that, generally, traffic calming schemes that included speed tables recorded mean speeds less than 50 km/h and excessive speeds ranging between 0 and 30%. Apeguusu was an exception to this finding in that excessive speeding (vehicles traveling above the posted speed limit of 50 km/h) still hover around 70% despite the inclusion of speed tables in the calming scheme. Notably, traffic calming schemes without speed tables were associated with mean speeds far greater than the 50 km/h limit and a higher proportion of motorists traveling above the speed limit. For example, Bechem, Ntonso, Denase, Anomabu, and Biriwa were among settlements in which over 80% of vehicles were traveling above the posted speed limit even though there were some traffic calming measures in place. Two reasons for this were found: first, the speeding countermeasures in these towns did not include speed tables and, second, most of the installations had worn out due to continuous usage without any maintenance.

In contrast, among settlements that have no traffic calming measures as presented in Table 1, the mean vehicular speeds were generally in excess of the posted speed limit of 50 km/h, varying from 55 km/h at Abofuor on the Kumasi–Techiman highway to 86 km/h at Atwedie on the Kumasi–Accra highway.

Traveling higher than the speed limit was generally more common in towns without any traffic calming devices compared to those with traffic calming measures. Among the settlements without any traffic calming schemes, excessive speeds ranged between the 60% at Abofuor and 100% at Egyirikrom and Sanfo Aduam, both on the Yamoransa–Kumasi highway,
Table 2. Impact of traffic calming on pedestrian traffic casualty severity in Ghana.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Injuries, n (%)</th>
<th>Crude OR</th>
<th>Adjusted OR</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed calming measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (referent)</td>
<td>76 (38)</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>124 (62)</td>
<td>1.95</td>
<td>1.78</td>
<td>1.09–4.43*</td>
</tr>
<tr>
<td>Speed table</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (referent)</td>
<td>15 (36)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>46 (64)</td>
<td>3.41</td>
<td></td>
<td>0.54–6.51</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (referent)</td>
<td>74 (37)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>126 (63)</td>
<td>1.12</td>
<td></td>
<td>1.08–2.46</td>
</tr>
<tr>
<td>Mean speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤50 km/h</td>
<td>67 (34)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;50 km/h</td>
<td>133 (66)</td>
<td>2.30</td>
<td></td>
<td>1.21–3.21</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–59</td>
<td>103 (53)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤17</td>
<td>78 (38)</td>
<td>1.24</td>
<td></td>
<td>1.17–2.36</td>
</tr>
<tr>
<td>&gt;60</td>
<td>17 (9)</td>
<td>2.74</td>
<td></td>
<td>2.13–7.77</td>
</tr>
<tr>
<td>Time of day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daytime (6:00 a.m. to 5:59 p.m.)</td>
<td>125 (63)</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nighttime (6:00 p.m. to 5:59 a.m.)</td>
<td>75 (37)</td>
<td>3.35</td>
<td>2.43</td>
<td>1.48–6.12*</td>
</tr>
</tbody>
</table>

*a95% Confidence intervals for adjusted variables.

and Supomu Dunkwa on the Cape Coast–Takoradi highway, as shown in Table 1.

Pedestrian casualty injury analysis

Two hundred and one pedestrian casualties were reported by the police in the selected settlements over the study period: 33% were fatalities, 53% were either slight injuries requiring no hospitalization or serious injuries requiring at least a 24-h hospitalization; and 14% were not injured. Casualty injury classes were dichotomized into 2 levels—fatal and nonfatal—for the SLR and multivariable conditional logistic regression analyses.

As shown in Table 2, 76 pedestrian casualties constituting 38% of pedestrian casualties occurred in settlements that have traffic calming schemes and 124 casualties representing 62% of the total pedestrian casualties in the study occurred in settlements with no traffic calming schemes. The SLR and multivariable conditional logistic regression analysis results are displayed in Table 2.

Association between pedestrian injuries and traffic calming measures

Pedestrian injury severity was significantly associated with traffic calming measures. After accounting for time of day, pedestrians’ gender and age, the adjusted OR for pedestrian fatalities was 1.78 times higher in settlements without traffic calming measures compared to settlements with traffic calming schemes (OR = 1.78; 95% confidence interval, 1.09–4.43). Comparing traffic calming schemes that have no speed tables to those that have speed tables revealed that the latter were more protective than the former. The odds of pedestrian fatality in settlements that have no speed tables were 3-fold higher than the odds of pedestrian fatality in towns that have speed tables.

Discussion

Traveling above the speed limit in built-up areas is a common practice in Ghana. This research shows that between 60 and 100% of drivers typically travel above the 50 km/h speed limit in settlements in Ghana when there are no traffic calming devices. Thus, pedestrians’ lives are endangered by speeding vehicles in towns along the major trunk roads. It is evident that traffic calming schemes are capable of controlling vehicle speeds and, consequently, reducing the incidence and severity of pedestrian–vehicle collisions along major interurban highways in Ghana. A pedestrian involved in a crash in settlements that have no traffic calming devices is twice as likely to be fatally injured compared to towns where traffic calming schemes are present. Among settlements that have traffic calming schemes, the protective effects were particularly pronounced if the traffic calming scheme included speed tables. The protective effects apparently decreased for calming schemes more than 5 years old without any maintenance. As Bishai and Hyder (2006) indicated, some traffic calming measures—for example, speed humps—have a life of up to 10 years. We recommend that any calming scheme that does not include speed humps or speed tables should be replaced periodically, say, every 5 years. The use of the traffic calming measures should, however, be restricted to residential streets and not urban arterial roads.

It is worth noting that Ghana inherited the road system from the colonial British regime and the main focus of road construction during that time was to link settlements as a way of opening up the country for development. Vehicle speeds and traffic volumes were notably low then. Several years later, traffic volumes on roads have increased, vehicle technology has improved tremendously, and cars now travel much faster. Yet, this tradition of high-speed roads passing through settlements has not changed. New roads are superimposed on old road alignments. Research has shown a greater association between pedestrian injuries, especially among children, and high traffic volumes (Christie 2000; Donroe et al. 2008; Roberts et al. 1995). Roberts et al. (1995), for example, noted that the risk of pedestrian injuries at locations with the highest traffic volumes was 14 times greater than that at sites with lower traffic volumes. Nevertheless, until recently, the installation of traffic calming devices in Ghana was an afterthought because they were provided only when residents demanded that traffic countermeasures be provided to slow down vehicles passing through their towns, usually after a couple of residents had died in vehicle–pedestrian collisions.

Installation of traffic calming schemes—that is, speed bumps, tables, and humps—does not entirely eradicate excessive speeding in settlements or preclude the occurrence of pedestrian injuries, especially when the schemes do not include speed tables. Rather, the incidence and severity of pedestrian injuries are ameliorated when traffic calming devices are installed. Long-term pedestrian safety strategies...
are proposed: Firstly, there is a need to bypass settlements along arterial roads (Derry et al. 2007). This will considerably reduce the traffic volumes and improve the general livability in these settlements. This may help to encourage motorists to drive at safer speeds when they are not constantly encountering such speed calming measures.

There is a great deal of pedestrian activity in Ghana; therefore, the new paradigm of road construction should be pedestrian focused, encouraging the provision of requisite pedestrian infrastructure (Damsere-Derry et al. 2017). Inclusion of sidewalks, crosswalks, paths, and pedestrian bridges will improve the livability of towns along the major highways in Ghana. City authorities should ensure that, when provided, these facilities are not taken over by hawkers but are used mainly for walking.

It is not clear whether the prevalence of motorists traveling above the speed limit in Ghana is because motorists regard the speed limits as inappropriate or due to weak enforcement. For compliance with speed limits to be high, a majority of motorists must perceive the rule to be legitimate and appropriate. Otherwise, large numbers of drivers may disregard the limit to such an extent that enforcement may be problematic (Transportation Research Board 1998).

Evidenced-based enforcement that utilizes deterrent theory should be adopted. For motorists to comply with speed limits there should be a high perceived risk of certainty of apprehension and punishment, celerity of punishment, and severity of punishment. In Queensland, Australia, for example, first-time speeding offenders traveling 40 km/h above the speed limit lose 8 demerit points and pay a fine of AUD 1,137 (Queensland Government 2017). This system of punishment will have a much more deterrent effect, particularly among commercial drivers whose livelihoods depend on driving a motor vehicle. This punishment regime will require providing police with state-of-the-art equipment for speed enforcement. The allegation of corrupt behavior among police should be addressed (Adu Gyamfi 2015; Myjoyonline.com 2016) so that these resources can be dedicated to enforcement.

Traffic calming devices have been proven to significantly reduce vehicle speeds and, consequently, improve pedestrian safety in Ghana. However, the fact that they are being deployed on arterial roads is increasingly becoming a road safety concern. The vast majority of vehicles traversing these settlements on trunk roads are bound for destinations farther away. Therefore, the tradition of routing major roads through towns should be reviewed. If detours were provided in future road planning, much of the traffic may use these bypasses, thereby minimizing the number of potential speed limit violators and ultimately prevent a greater proportion of potential vehicle–pedestrian collisions. In addition, enforcement that uses demerit points should be adopted for long-term speed control in Ghana.

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