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Geographical mapping of road traffic injuries in Lilongwe, Malawi

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ABSTRACT

Background: Road traffic injuries are a leading cause of death and disability, especially in low- and middle-income countries. Identifying injury hotspots are valuable for introducing preventive measures. This is usually accomplished by using police data, but these are often unreliable in low-income countries. This study aimed to identify hotspots for injuries by collecting geographical data in the emergency room.

Methods: This was a cross-sectional study of adult road traffic injury patients presenting to the Casualty Department in the central hospital in Lilongwe, the capital of Malawi. An electronic tablet with downloaded maps and satellite photos was used to establish the exact location of the injuries. The geographical data were analyzed with geographic information software.

Results: We included 1244 road traffic injured patients, of which 23.9% were car passengers or drivers, 18.6% were motorcyclists, 17.8% were pedestrians and 18.0% were cyclists or bicycle passengers. Heatmaps of the injuries identified 5 locations where the incidence of injuries was especially high, and 148 patients were injured in these hotspots during the 90 days of inclusion. Four of these hotspots were along the main road through the capital. Age over 55, rural setting, alcohol use before the injury, high speed limit at the site of injury and being a pedestrian or motorcyclist were significantly associated with a higher degree of injury severity. Around half of the patients that were injured in a four-wheeled vehicle did not use a seat belt, and these patients had a much higher risk of getting a more severe injury.

Conclusion: We have identified specific locations with a high incidence of road traffic injuries in Lilongwe, Malawi, with a simple methodology and within a short time frame. The study demonstrates the feasibility of collecting geographical data at admission to hospital.

Introduction

Annually, 1.35 million people are estimated to die from road traffic injuries (RTI), and 93% of these deaths occur in low and middle income countries [1]. Globally, road traffic injuries are the leading cause of death in young people aged 9-25 years, and more people die from road traffic injuries than from HIV/AIDS, tuberculosis or diarrheal diseases [2]. The low income countries (LIC), which include countries with a GDP per capita of less than 1006 USD, have 9% of the worldś population, 1% of the world's vehicles and 13 % of the world's road traffic deaths [1].

Prevention of road traffic injuries is one of the major public health success stories in high income countries. For example, the age-standardized incidence of road traffic deaths in OECD countries decreased by more than 70% between 1990 and 2013 [3]. To develop strategies to prevent road traffic injuries and deaths, it is imperative to have local knowledge and research on the precise nature of these injuries. In high-income countries precise statistics and data collection on road traffic injuries are a highly prioritized

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task [4], but in low-income countries, the research on these issues is scarce.

Among the most effective interventions for reducing road traffic injuries in low-and middle-income countries are modifications of the physical infrastructure; for example, the construction of speed bumps at junctions known for a high risk of injuries was shown to be very cost-effective in one study from 2006, with an estimated cost for Sub-Saharan Africa of only 1.6 to 6.2 USD per disability-adjusted life year (DALY) saved, depending on how many injuries occur at the junction and the discounting rate in the calculation [5]. Restructuring the physical environments around schools has been shown to be effective in reducing the rate of road traffic injuries in a controlled study from Tanzania [6]. A large case-control study from Ghana showed that speed bumps and speed tables were very effective in reducing speed, and also significantly lowered the risk of fatal injuries where they were present [7].

In a very resource limited setting, it is important to maximize the effect of such interventions by identifying the locations where they will be most effective. A promising methodology for this is the geographical analysis of injuries using geographical information systems (GIS) software [8], with exact geographical coordinates as input data. This allows for a precise analysis of hotspots of injury, making it possible to evaluate possible interventions of the built environment, or for more efficient law enforcement in specific areas. This methodology has been demonstrated in Kenya, where registrations from a commercial traffic reporting app were used to map road traffic injuries reported by the app users [9]. In Kigali, Rwanda, they used police records and GIS-software to identify hotspots for different types of traffic users [10]. There was, however, concern about the quality and completeness of the police data, as also expressed in similar studies from Tanzania [11,12] and Guyana [13].

In Malawi, the completeness of police records is questionable. In 2015, the police records showed a total of 1060 deaths due to road traffic injuries [14], approximately the same number as in 1990, when the population was approximately half of today's [15]. The WHO estimate for road traffic deaths in Malawi in 2016 was 5601 [1], demonstrating a large discrepancy. In 2012, Samuels and co-workers published a study from Lilongwe where they utilized a capture-recapture method with both hospital records and police records from 2008 [16]. The police records showed an incidence of 7.5 deaths per 100 000 inhabitants, but after capture/recapture analysis with the hospital records, the incidence was estimated to be 19.2-20.9/100 000, clearly showing the inadequacy of the police records. As 82 of the 97 hospital deaths in this study were dead on arrival, the inaccuracy of police numbers cannot be ascribed to late hospital deaths not being recorded.

To our knowledge, all previous studies using exact coordinates for mapping of road traffic injuries have utilized data collected prehospitally or from coordinates derived from addresses or place names. The aim of our present study was to investigate the feasibility of in-hospital collection of injury location by using map software on a tablet, in order to generate precise data on road traffic injury distribution and characteristics. We also wanted to identify factors associated with more severe injuries.

Materials and methods

Local setting

The site of the study was Kamuzu Central Hospital (KCH), the main public hospital in the capital of Malawi, Lilongwe. KCH has 900 beds and is a university teaching hospital. It serves as the regional trauma centre for the Central Region of Malawi, which has a population of approximately 7.5 million. Treatment is free of charge. There are 8 district hospitals in the region treating road traffic injuries, as well as several mission hospitals, but severe cases are usually referred to KCH. Within the city of Lilongwe, with 1.6 million inhabitants, the hospital serves as a primary hospital. There is also a district hospital and several small private hospitals within the city that offers treatment for less severe road traffic injuries.

Data collection

Data collection was performed in the Casualty Department (i.e. Emergency room) at Kamuzu Central Hospital from May 25 to August 22, 2019. All patients with road traffic injuries and age above 18 years that were attended to in the KCH Casualty Department were asked to participate in the study. The legal age of consent in Malawi is 18, and persons under that age were therefore not included. Only patients with a possible need for in-hospital treatment are attended to in this department, while most patients with minor wounds and fractures are normally treated in the Outpatient Department and are not included in the study. Exclusion criteria were injury victims younger than 18 years, those brought in dead and those who did not consent. Those who could not give consent immediately, for example due to altered state of consciousness, were included and consent was obtained later. The data was deleted if consent was not obtained later.,

The inclusion and data collection were done by 2 qualified medical doctors, trained and employed by the project, working shifts in the casualty department day and night to cover all eligible patients to ensure best possible completeness of data in the study period.

Geographical positioning was done with a Google map application on an electronic tablet. The patients were shown the aerial photos of the relevant place and, with help of the interviewer, asked to identify the place of the RTI as precisely as possible. The WGS 84 Web Mercator coordinates were copied from the tablet application and pasted into the database using FileMaker Pro software.

Apart from the precise geographical position of the incident resulting in the injury, the expected prognosis of the patients, time from injury to casualty, demographical data and details about the RTI were recorded. Patients were asked about alcohol use before the injury, and they were tested for alcohol with a breathalyser test (Dräger Alcotest 5820, Drägerwerk AG & Co., Lübeck, Germany) or a saliva test (QED A150, Orasure Technologies, Inc., Bethlehem, PA, USA).

Data analysis

Patients who had previously presented at another private or public hospital or a health centre were defined as referral patients. Patients were classified as "alcohol positive" if they confirmed the use of alcohol in the hours before the injury, or if they tested positive using breathalyser or saliva testing. A mass casualty was recorded when 4 or more patients were injured in the same geographical location at the same time [17]. The prognosis of the crash-related injuries was classified according to an internal classification into 5 groups; expected full recovery, expected minor long-term disability, expected moderate disability, expected major disability or likely fatal injury, with a more detailed description of each category. A serious injury was recorded when the expected outcome of the injury was a moderate disability or worse, according to the above-mentioned classification system. Light-reduced conditions was defined as between 17:30 and 05:29. Seat belt use was recorded for all patients travelling in 4-wheeled vehicles, also those travelling on the beds of lorries.

Geographical analysis was performed with QGIS software (version 3.4, QGIS Geographic Information System, Open Source

Geospatial Foundation Project; www.qgis.org), using the Open Street Map as the map layer. Using the heatmap function in this program, maps were produced that visualized hotspots. By identifying the specific injured patients at these hotspots, the road user composition and types of injuries could be analysed further. The definition of a hotspot is controversial in the literature [18]. In this paper it is defined as a geographical area with an increased incidence of injuries compared to other areas, as visualized from the heatmaps.

Statistical analysis was done using STATA (version 15, College Station, TX, USA). Logistic regression was used to predict factors that could increase the risk of sustaining a severe injury. The analysis was adjusted by correcting for possible confounders; being referred from another facility, gender, age and alcohol positive status. Results of these analyses are presented with crude and adjusted Odds Ratios with 95% confidence intervals. One single imputation of the alcohol status of one patient was done, in one of the adjusted analyses. The manuscript was prepared adhering to the principles of the STROBE statement [19].

Ethical issues

Participation in the study was voluntary. All patients received oral and written information in English or Chichewa and provided a written consent. The study was approved by the Malawi National Health Sciences Research Committee (NHSRC, approval 1962/2018). The data handling procedures of the study was reviewed and approved by the Data Protection Officers of the Norwegian Institute of Public Health and Diakonhjemmet Hospital. The Norwegian Regional Health Research Committee was consulted, according to the Norwegian Health research act there was no need for a formal review of the project.

Results

Overview and predictors of severity

In total, 1347 road traffic injury patients fulfilled the inclusion criteria and were asked for consent. 88 patients (6.5%) declined to participate or were never able to give consent. Of the remaining 1259 included patients, 15 patients did not have a recorded geographical position, leaving 1244 patients for analysis in this study. There were 16 missing values for gender, 13 missing values for age, 8 missing values for alcohol status and 8 missing values for the patientś vehicle. 12 patients had missing information about severity.

Rural setting, high speed limit at the site of injury and pedestrian or motorcyclist status were significantly associated with a higher degree of injury severity (Table 1). There were very few serious injuries among those that were reported to have used a seat belt (1.5%), but around half of the patients that were injured in a four-wheeled vehicle had not used a seat belt. Those patients had a much higher risk of suffering a serious injury. Patients who had consumed alcohol before the injury or were referred from another hospital or health centres also had a higher proportion of severe cases. Details about the prevalence of alcohol consumption in different road users, as well as details about the time of the injuries have been described in a different article [20].

Geographical analysis

Fig. 1 shows the distribution of injuries on a map of the Central Region of Malawi. As the hospital is a tertiary central hospital, patients are referred from the whole of Central Region. The distribution shows that the majority of the road traffic crashes resulting in patients coming to KCH occurred in and around the city of Lilongwe, and along the major highways.

Hotspot analysis

Fig. 2 shows a QGIS heatmap of all injuries, visually identifying 5 different hotspots, where 148 patients were injured during the study period. These hotspots are described further in Table 2, and in Fig. 3 heatmaps are made for different types of road users.

Mass casualties

We identified 35 mass casualties with 4 or more injured persons, with a mean of 7 injured and a median of 5 injured. The 3

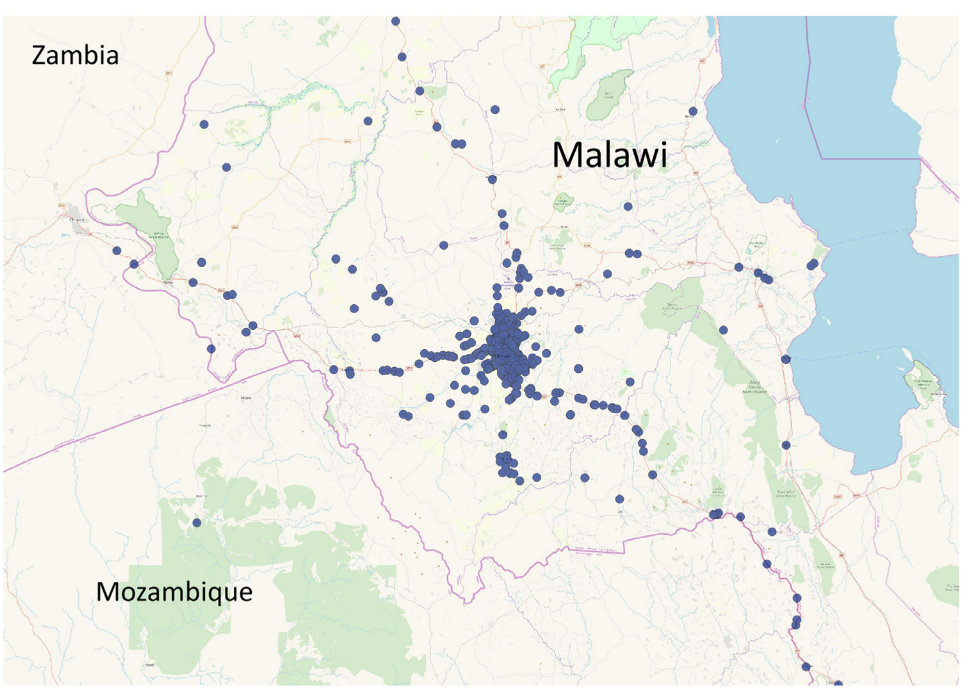

Fig. 1. Map of central Malawi with all injures plotted.

Table 1
Description of the study population, with risk factors for serious injuries.

	All injuries n (%) 1244	Serious injuries[†] n (%) 121 (9.8)	Mild injuries n (%) 1111 (90.2)	Crude Odds Ratio for serious injury	Adjusted Odds Ratio[‡]
Age groups					
18-24	252 (20.5)	15 (6.0)	236 (94.0)	1	1
25-34	475 (38.6)	47 (10.0)	422 (90.0)	1.75 (0.96-3.20)	1.57 (0.84-2.95)
35-44	296 (24.1)	23 (7.9)	270 (92.1)	1.34 (0.68-2.63)	1.19 (0.48-2.40)
45-54	135 (11.0)	13 (9.7)	121 (90.3)	1.69 (0.78-3.67)	1.48 (0.65-3.36)
55-64	45 (3.7)	8 (18.2)	36 (81.8)	3.50 (1.38-8.83)*	3.33 (1.25-8.93)*
65+	28 (2.3)	6 (21.4)	22 (78.6)	4.29 (1.51-12.17)*	5.42 (1.81-16.24)*
Median transport time (min)	75	185	70		
Gender					
Female	239 (19.5)	13 (5.5)	225 (94.5)	1	1
Male	989 (80.5)	107 (10.9)	871 (89.1)	2.12 (1.17-3.85)*	1.87 (0.98-3.56)
Referral status					
Direct to KCH	1012 (81.3)	68 (6.7)	935 (93.2)	1	1
Referred	232 (18.7)	53 (23.1)	176 (76.7)	4.14 (2.79-6.14)*	5.20 (3.41-7.93)*
Type of site					
Urban site	924 (74.9)	61 (6.7)	852 (93.3)	1	1
Rural site	309 (25.1)	58 (18.8)	250 (81.2)	3.24 (2.20-4.77)*	2.41 (1.49-3.90)*
Speed limit					
50-60 km/h	1029 (84.9)	90 (8.8)	930 (91.2)	1	1
Unknown	138 (11.4)	17 (12.4)	120 (87.6)	1.46 (0.54-2.54)	0.78 (0.41-1.47)
100 km/h	45 (3.7)	13 (28.9)	32 (71.1)	4.20 (2.13-8.28)*	2.27 (1.02-5.06)*
Light-reduced conditions					
No (05:30-17:29)	699 (56.7)	61 (8.7)	638 (91.3)	1	1
Yes (17:30-05:29)	533 (43.3)	60 (11.3)	473 (88.7)	1.33 (0.91-1.93)	1.13 (0.73-1.75)
Seat-belt use (if applicable)					
Yes	259 (48.0)	255 (98.5)	4 (1.5)	1	1
No	281 (52.0)	257 (91.5)	24 (8.5)	5.95 (2.04-17.4)*	4.49 (1.47-13.76)*
Type of traffic user					
Car passenger or driver	295 (23.9)	13 (4.5)	278 (95.5)	1	1
Bicyclist/passenger	223 (18.0)	19 (8.6)	203 (91.4)	2.00 (0.97-4.14)	1.74 (0.80-3.81)
Cab of lorry	19 (1.5)	1 (5.3)	18 (94.7)	1.19 (0.15-9.60)	1.00 (0.11-8.74)
Bed of lorry	118 (9.6)	10 (8.5)	108 (91.5)	1.98 (0.84-4.65)	1.86 (0.75-4.61)
Minibus	120 (9.7)	4 (3.4)	114 (96.6)	0.75 (0.23-2.35)	0.94 (0.29-3.07)
Motorcycle	230 (18.6)	26 (11.4)	202 (88.6)	2.75 (1.38-5.49)*	2.26 (1.07-4.76)*
Other[§]	11 (0.9)	4 (36.4)	7 (63.6)	12.22 (3.17-47.07)*	6.75 (1.59-28.63)*
Pedestrian	220 (17.8)	44 (20.2)	174 (79.8)	5.40 (2.83-10.32)*	3.93 (1.93-8.01)*
Type of incident					
Mass casualty	245 (19.7)	8 (3.3)	234 (96.7)	1	1
1-3 injured in same incident	999 (80.3)	113 (11.4)	877 (88.6)	3.77 (1.81-7.83)*	3.18 (1.43-7.09)*
Alcohol status					
Alcohol negative	928 (75.1)	70 (7.6)	849 (92.4)	1	1
Alcohol positive	308 (24.9)	44 (14.4)	261 (85.6)	2.04 (1.37-3.05)*	1.74 (1.11-2.74)*

[†] 12 patients have missing values for severity, so columns don't add up.
[‡] Adjusted for age, gender, alcohol use and referral status.
[§] Bus passenger, ox cart passenger or driver, or unspecified.
[*] $p<0.05$.

largest mass casualties were lorry crashes, where 15, 24 and 35 people were injured. As Table 1 shows, being involved in a mass casualty was associated with less risk of a serious injury in this study.

Discussion

This study has shown the feasibility of collecting precise geographical information with an electronic tablet in the emergency room, and it has identified hotspots for road traffic injuries in the city of Lilongwe.

Method of data collection

Most other studies on geospatial mapping of road traffic injuries have used police records. There are, however, concerns about the completeness of such records, and there is a high risk of bias being introduced by the presence or absence of police in different areas or at different times. Most likely, many injuries with low severity are not recorded by the police. We demonstrate that in-hospital recording also can provide valuable results, and that it can be done in a simple and cheap way, with free software. Though in-hospital recording has its limitations, most notably that immediately fatal injuries are not recorded, we still believe that they give a more complete picture of the geographical distributions of road traffic injuries, as most injured patients find their way to the hospitals if they survive. Many patients obviously seek other hospitals, which make conclusions regarding the rural areas far from the city difficult, and this study therefore was focused on Lilongwe city itself. Within the city there are also other private and public hospitals that patients may have utilized, making the present material far from complete.

Hotspot analysis

Our definition of a hotspot as a geographical area with an increased incidence of injury compared to other areas is controversial [18]. The road traffic researcher Rune Elvik proposes this definition of a hazardous road location: any location that (a) has a higher expected number of crashes (b) than other similar locations (c) as a result of local risk factors [21]. The hotspots we have established in Lilongwe are along the main highway, and they are possibly the busiest junctions in the whole country. It is actually

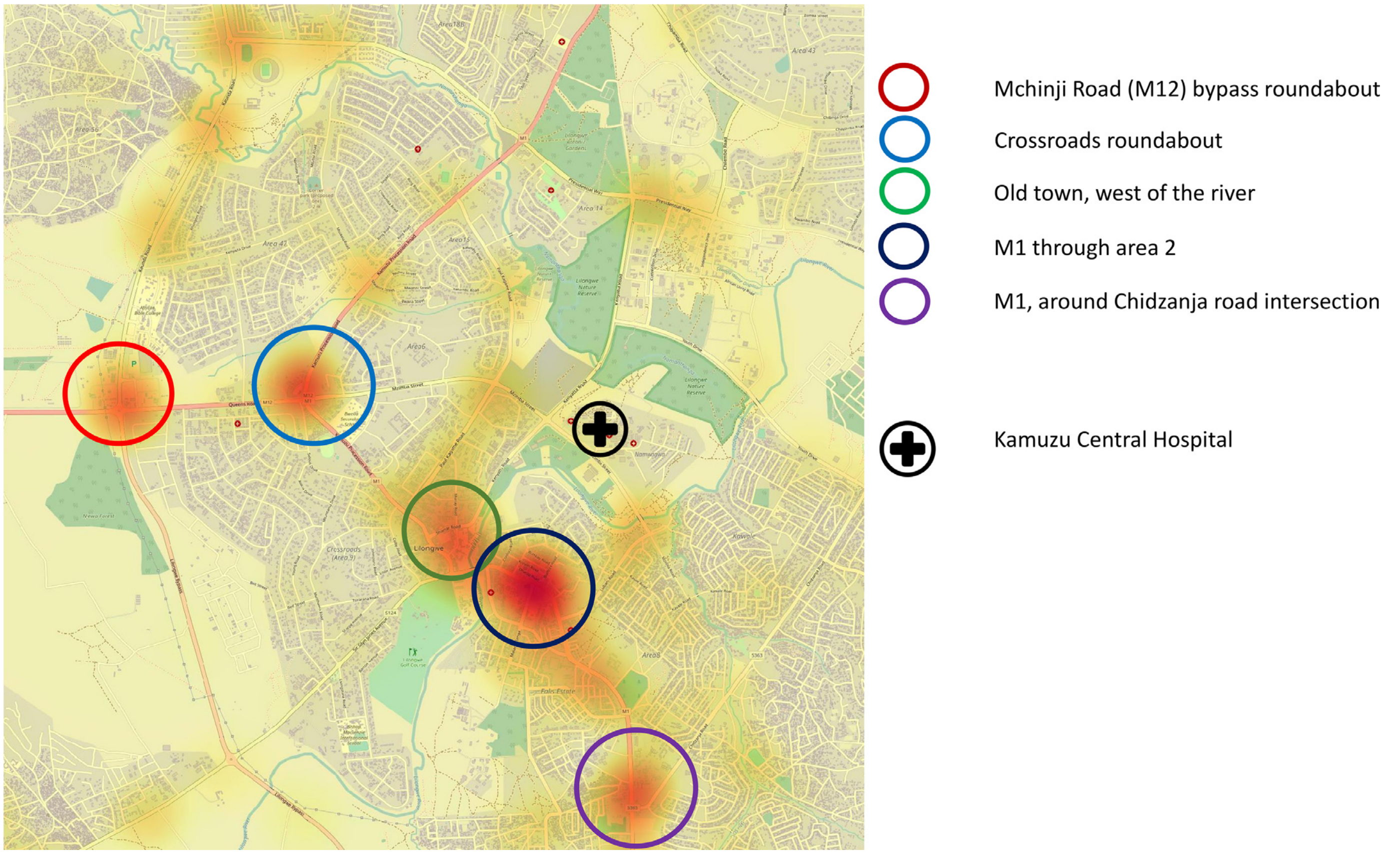

Fig. 2. Hotspots for all types of road users.

theoretically possible that the physical infrastructure and law enforcement practices in these hotspots are as good as they possibly can be, and that the increased rate of injuries is only a function of the traffic volume. To establish if these junctions really are hazardous in Elvikś sense of the term, it would be necessary to do statistical modelling comparing with other junctions, and this would require long term data on traffic volume and injury risk, currently not available in this low-income setting.

Injury severity

Patients that had consumed alcohol before the injury, had more severe injuries. This is also reported in several other studies [22–24]. We also found that patients from rural areas had a larger proportion of serious injuries, even when adjusting for referral cases, and the same phenomenon is also reported in Ethiopia [22] and Guyana [13]. A possible explanation for this is that the speed of vehicles is most often higher in the rural areas. In the urban areas, there is congestion of the traffic during rush hours, and vehicle speeds can be very low. The roads with high speed limit are mostly in rural areas. We found the same phenomenon reflected in that severity is higher in patients injured on a road with a 100 km/h speed limit, consistent with common knowledge about the crucial importance of speed when it comes to injury severity [25]. Drivers and passengers that were not using seatbelts, including passengers in minibuses and on the beds of lorries, had a much higher risk of getting a more severe injury.

A surprising finding was that those involved in mass casualties had a significantly lower risk of sustaining a severe injury. We suspect that the reason for this might be that often when such an incident occurs, a major transport operation to the hospital is arranged, possibly over-triaging and bringing also less severely wounded patients along to the hospital. Pedestrians were more severely injured than other traffic users in this study, and this is not surprising considering their vulnerable nature. Details about the injuries sustained by pedestrians and bicylists in this study has been analysed in another paper [26], which showed that the majority (60.2%) were injured while walking or cycling along the road, while 22.3% were injured while crossing the road. Interestingly, being injured while crossing the road on a painted zebra crossing led to significantly more serious and potentially fatal injuries, pointing to the importance of providing safer modes of crossing the road for these vulnerable road users.

Implications for prevention

Measures that modify the physical environment in the locations where injuries happen, are among the most effective and cost-efficient that are described in the literature. The well-known calculation by Bishai and Hyder that the building of speed bumps prevented RTI deaths at a price of only 2.26 USD (2001 US dollars, discounted 3%) per DALY in Sub-Saharan Africa [5], is based on that this is done on only the most dangerous junctions, and they estimate that in a city with a population of 1 million people, there will be 6 junctions responsible for 10% of traffic deaths. This is not far from the findings of our study; 5 hotspots with around 13% of the injuries were identified in this city of 1.6 million people. By using this information, the physical environment of these hotspots can be modified, and this will most likely be highly cost-effective compared to other preventive measures for road traffic injuries, or perhaps most other public health interventions. Construction of speed bumps is one possible intervention, but speed tables (where the bumps are elongated with a flat top) was shown

Table 2
Descriptions of hotspots from Figure 2 (photos by M. Sundet)

Mchinji Road (M12) bypass roundabout There were 21 injuries in this roundabout, but 15 of them occurred in the same incident when a lorry carrying many people on the cargo bed crashed. The location of this might therefore be incidental.	
Crossroads roundabout 28 injuries were sustained here during the study period. There were 2 mass casualties, 10 people were injured when a car hit a crowd in a petrol station. The distribution of other traffic users is about the same as in the rest of the material	
Old town, west of the river 35 people were injured here, including one mass casualty with 5 injured in a car crash. The types of vehicles had approximately the same distribution as elsewhere.	
M1 through area 2 44 people were injured here, including 7 people in a minibus mass casualty, and 4 people in another mass casualty with unclear circumstances.	
M1 around Chidzanja road intersection This hotspot had 20 injuries, of which 5 were motorcycle drivers. This is significantly more than for the other hotspots, and this is also visible on figure 3, where heat maps are made for different types of traffic users. From this figure, a motorcycle hotspot is visible in this intersection. There were no mass casualties at this hotspot.	

to be more effective in a recent study from Ghana [7]; this has to be evaluated and designed by skilled engineers.

Another cost-effective measure is to increase the traffic enforcement by the police. In a study from Uganda this was estimated to decrease the number of fatalities by 17%, at a cost of USD 27 per DALY averted [27]. To do this cost effectively, it is however necessary to know the major hotspots of injuries in the particular town or area. In our study, 148 people were injured in 5 locations in a time span of only 90 days, and increasing police presence at these hotspots is likely to be cost-effective.

Limitations

The main limitations of the study are the lack of information about fatal injuries at the scene, and the possible bias caused by the presence of other hospitals in the study area. Selection bias is

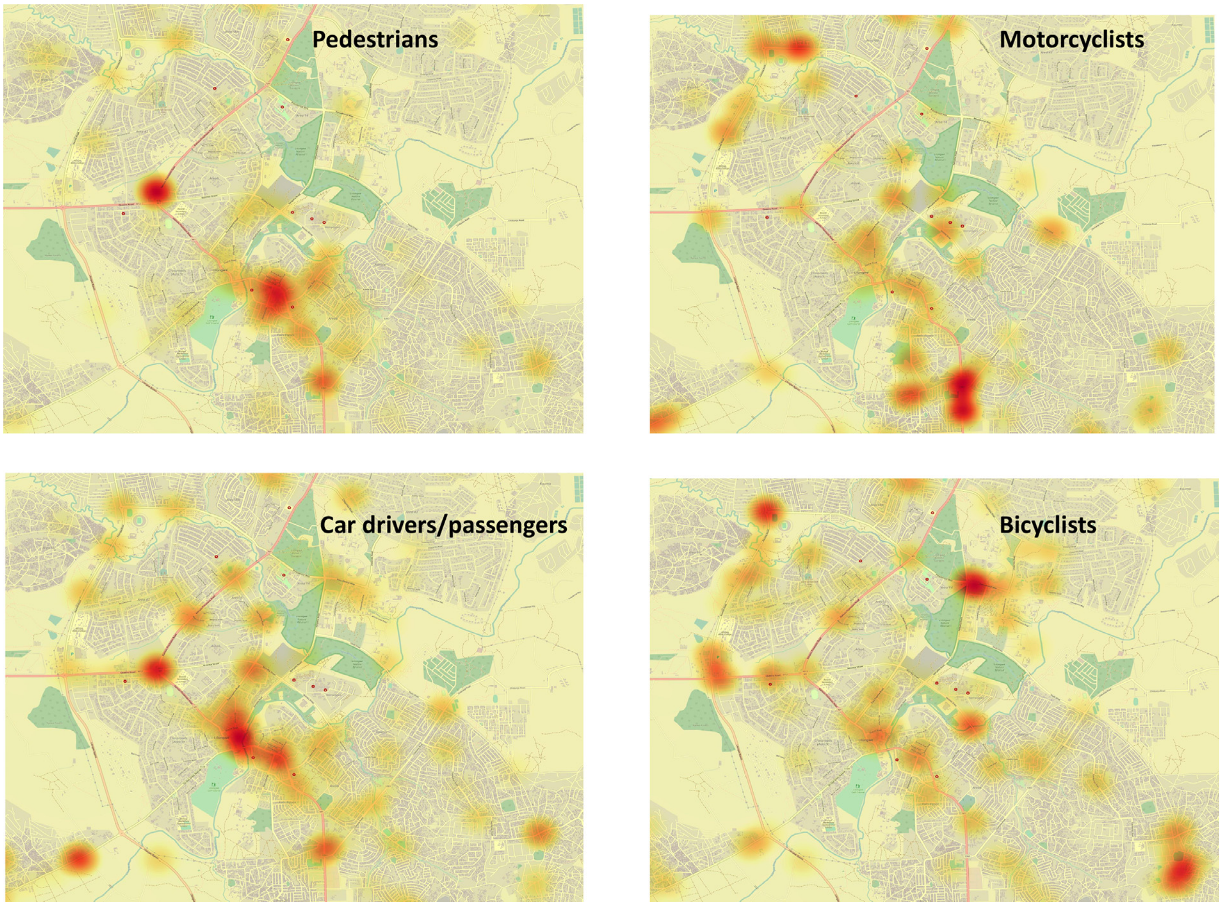

Fig. 3. Heatmaps for different road users.

likely to have contributed to the finding that injuries from rural areas were more severe, even if we have adjusted for referral status in the analysis. More severe cases from rural areas are most likely sent directly to the Central hospital, while minor cases go to district hospitals.

We had no way of checking the precision or correctness of the geographical positions recorded, but the RTI victims were helped by trained interviewers to identify the location as precisely as possible. More severely injured patients may have had more difficulties localizing their place of injury. Our definition of a hotspot is the simplest possible, and an analysis including traffic volume would give more valuable information regarding preventive measures.

The study also has clear strengths, including its size and the relative completeness of data during the inclusion period.

Conclusion

We have identified 5 hotspots, where 148 people were injured in the span of 90 days. Those who consumed alcohol before the injury, those over the age of 55, those not using a seat belt, pedestrians, motorcyclists, people injured in rural areas or where the speed limit was 100 km/h suffered more severe injuries. Our study is probably the first to demonstrate that mapping of road traffic injuries using information recorded on a tablet in the emergency room is feasible and can give valuable results. The presented results are relevant for the introduction of affordable and cost-effective prevention efforts.

Declaration of Competing Interest

None.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2021.02.028.

References

[1] World Health Organization (WHO) Global status report on road safety. Geneva: World Health Organization; 2018.
[2] 2017 Global Burden of Disease Database n.d. http://www.healthdata.org/gbd.
[3] OECD Health at a Glance 2015. Paris: OECD; 2016. doi:101787/health_glance-2015-en.

[4] Lord D, Washington S. Safe mobility: challenges, methodology and solutions. Safe mobil. challenges, methodol. solut., vol. 11. Lord D, Washington S, editors. Emerald Publishing Limited; 2018. p. i–xxxii. doi:10.1108/S2044-994120180000011024.
[5] Bishai DM, Hyder AA. Modeling the cost effectiveness of injury interventions in lower and middle income countries: opportunities and challenges. Cost Eff Resour Alloc 2006;4(2). doi:10.1186/1478-7547-4-2.
[6] Poswayo A, Kalolo S, Rabonovitz K, Witte J, Guerrero A. School area road safety assessment and improvements (SARSAI) programme reduces road traffic injuries among children in Tanzania. Inj Prev 2019;25(5):414–20. doi:10.1136/injuryprev-2018-042786.
[7] Damsere-Derry J, Ebel BE, Mock CN, Afukaar F, Donkor P, Kalowole TO. Evaluation of the effectiveness of traffic calming measures on vehicle speeds and pedestrian injury severity in Ghana. Traffic Inj Prev 2019;20:336–42. doi:10.1080/15389588.2019.1581925.
[8] Singh H, Fortington LV, Thompson H, Finch CF. An overview of geospatial methods used in unintentional injury epidemiology. Inj Epidemiol 2016;3:32. doi:10.1186/s40621-016-0097-0.
[9] Shaw BI, Wangara AA, Wambua GM, Kiruja J, Dicker RA, Mweu JM, et al. Geospatial relationship of road traffic crashes and healthcare facilities with trauma surgical capabilities in Nairobi, Kenya: defining gaps in coverage. Trauma Surg Acute Care Open 2017;2:1–5. doi:10.1136/tsaco-2017-000130.
[10] Patel A, Krebs E, Andrade L, Rulisa S, Vissoci JRN, Staton CA. The epidemiology of road traffic injury hotspots in Kigali, Rwanda from police data. BMC Public Health 2016;16:697. doi:10.1186/s12889-016-3359-4.
[11] Reardon JM, Andrade L, Hertz J, Kiwango G, Teu A, Pesambili M, et al. The epidemiology and hotspots of road traffic injuries in Moshi, Tanzania: an observational study. Injury 2017;48:1363–70. doi:10.1016/j.injury.2017.05.004.
[12] Waldon M, Ibingira TJ, de Andrade L, Mmbaga BT, Vissoci JRN, Mvungi M, et al. Built environment analysis for road traffic hotspot locations in Moshi, Tanzania. Int J Inj Contr Saf Promot 2018;25:272–8. doi:10.1080/17457300.2018.1431941.
[13] McWade CM, McWade MA, Quistberg DA, McNaughton CD, Wang L, Bux Z, et al. Epidemiology and mapping of serious and fatal road traffic injuries in Guyana: results from a cross-sectional study. Inj Prev 2017;23:303–8. doi:10.1136/injuryprev-2016-042119.
[14] Malawi government Directorate of Road Traffic and Safety Services. Road Traffic Accident Situation Annual report 2015. Lilongwe: 2015.
[15] Olukoga A. Trends in road traffic crashes, casualties and fatalities in Malawi. Trop Doct 2007;37:24–8. doi:10.1258/004947507779951871.
[16] Samuel JC, Sankhulani E, Qureshi JS, Baloyi P, Thupi C. Under-reporting of road traffic mortality in developing countries: application of a capture-recapture statistical model to refine mortality estimates. PLoS One 2012;7:31091. doi:10.1371/journal.pone.0031091.
[17] Castro Delgado R, Naves Gómez C, Cuartas Álvarez T, Arcos González P. An epidemiological approach to mass casualty incidents in the principality of Asturias (Spain). Scand J Trauma Resusc Emerg Med 2016;24:1–9. doi:10.1186/s13049-016-0211-x.
[18] Elvik R. State-of-the-art approaches to road accident black spot management and safety analysis of road networks. TØI report 883/2007. Oslo: 2007.
[19] Vandenbroucke JP, von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the reporting of observational studies in epidemiology (STROBE): explanation and elaboration. Int J Surg 2014;12:1500–24. doi:10.1016/j.ijsu.2014.07.014.
[20] Sundet M, Kajombo C, Mulima G, Bogstrand ST, Varela C, Young S, et al. Prevalence of alcohol use among road traffic crash victims presenting to a Malawian central hospital: a cross-sectional study. Traffic Inj Prev 2020. doi:10.1080/15389588.2020.1819990.
[21] Elvik R. Comparative analysis of techniques for identifying locations of hazardous roads. Transp Res Rec 2008;2083:72–5. doi:10.3141/2083-08.
[22] Baru A, Azazh A, Beza L. Injury severity levels and associated factors among road traffic collision victims referred to emergency departments of selected public hospitals in Addis Ababa, Ethiopia: the study based on the Haddon matrix. BMC Emerg Med 2019;19:1–10. doi:10.1186/s12873-018-0206-1.
[23] Stübig T, Petri M, Zeckey C, Brand S, Müller C, Otte D, et al. Alcohol intoxication in road traffic accidents leads to higher impact speed difference, higher ISS and MAIS, and higher preclinical mortality. Alcohol 2012;46:681–6. doi:10.1016/j.alcohol.2012.07.002.
[24] Shyhalla K. Alcohol involvement and other risky driver behaviors: effects on crash initiation and crash severity. Traffic Inj Prev 2014;15:325–34. doi:10.1080/15389588.2013.822491.
[25] World Health Organization (WHO). Managing speed. Geneva: 2017.
[26] Sundet M, Mulima G, Kajombo C, Gjerde H, Christophersen AS, Young S. Adult pedestrian and cyclist injuries in Lilongwe, Malawi: a cross-sectional study. Malawi Med J 2020;32.
[27] Bishai D, Asiimwe B, Abbas S, Hyder AA, Bazeyo W. Cost-effectiveness of traffic enforcement: case study from Uganda. Inj Prev 2008;14:223–7. doi:10.1136/ip.2008.018341.