HHS Public Access

Author manuscript

Injury. Author manuscript; available in PMC 2018 July 01.

Published in final edited form as:

Injury. 2017 July ; 48(7): 1363–1370. doi:10.1016/j.injury.2017.05.004.

The Epidemiology and Hotspots of Road Traffic Injuries in Moshi, Tanzania: an observational study

Joseph M Reardon, (JMR) MD[1], **Luciano Andrade, (LA) PhD**[2], **Julian Hertz, (JH) MD**[1], **George Kiwango, (GK) MD**[3], **Anneth Teu, (AT) MD**[3], **Msafiri Pesambili, (MP)**[3], **Deena El-Gabri, (DE) MScGH**[4], **Michael Hocker, (MH) MD**[1], **Mark Mvungi, (MM) MD**[3], **João Ricardo N Vissoci, (JRNV) PhD1**[1,4,5,*], and **Catherine A. Staton, (CAS) MD, MScGH**[1,4,5]

[1]Division of Emergency Medicine, Departmento of Surgery. Duke University Medical Center, Durham, North Carolina, United States of America

[2]Department of Medicine, State University of Maringa, Maringa, Parana, Brazil

[3]Kilimanjaro Christian Medical Centre, Moshi, Tanzania

[4]Division of Global Neurosurgery and Neuroscience, Department of Neurosurgery. Duke Univertsity School of Medicine. Durham, North Carolina, United States of America

[5]Duke Global Health Institute, Duke University, Durham, North Carolina, United States of America

Abstract

Road traffic injuries (RTIs) continue to increase with the proliferation of motor vehicles, especially in low-income countries where safe road infrastructure is lacking Knowing where and why RTIs occur would allow for increased safety and prevention planning. In this study, police records of 300 motor vehicle collisions which occurred between February 2013 and January 2014 in Moshi, Tanzania, were reviewed. Analysis of variables including victim age, gender, type of collision, conditions, and use of safety equipment were analyzed. Geographic information system (GIS) analysis was performed to identify areas with the most collisions. Most injuries occurred at four intersections on two main corridor. Car crashes represented 48% of reports while motorcycle collisions were 35% of reports. Victims were predominantly male. The majority (64%) of RTI victims in cars used seatbelts while only 43% of motorcyclists wore helmets; none of those who used the helmet or seatbelt suffered a grievous injury. These data demonstrate that RTIs in Moshi occur in predictable high traffic locations. RTIs injure victims of all backgrounds and safety equipment is not universally utilized. More investment is needed in improved data collection methods, and a greater emphasis on intersection safety is needed to reduce these preventable injuries.

[*]Corresponding author: Joao Ricardo Nickenig Vissoci, 1116 Stacey Glen CT, 27705, Durham, North Carolina, United States of America, Tel.+19197979228, jnv4@duke.edu.

Keywords

Road traffic injuries; Tanzania; Hotspot analysis

Introduction

About 1.25 million people die and 80 million people are injured from road traffic collisions each year[1]. About 90% of road traffic injuries (RTIs) occur in low and middle-income countries[2], costing between 3–10% of gross domestic product per year[3]. Road traffic crashes (RTCs) continue to increase with the proliferation of motor vehicles and are predicted to become the 3rd leading cause of disability and disability-adjusted life years lost by 2030; this burden especially impacts young and economically active populations in low-income countries where safe road infrastructure is lacking[4,5]. The scope of this problem is only partially described in scattered, incomplete analyses, which point to large scale morbidity and health care costs[6]. In low-income countries, the exact burden of injuries is difficult to define because of limited data regarding the epidemiology of RTCs and RTIs in these settings[7,8].

RTIs are preventable. Cost-effective interventions include the installation of speed bumps, improvements in road pavement conditions, visibility, signage, and helmet use [[9]]. While these interventions are more common in high resource settings, they nonetheless represent relatively affordable options for resource-poor countries[10]. The primary barriers to improvements in road safety are thought to be organizational and logistical[11]. Only 28 countries representing 7% of the world's population have adequate laws addressing relevant factors in RTCs, such as speed, alcohol, helmets, and restraints[12].

Half of all RTC deaths are among vulnerable road users (VRUs); motorcyclists, cyclists, and pedestrians[13]. Resource-poor settings have more VRUs, and these VRUs are more likely to be injured due to a lack of safety equipment, lack of safety infrastructure, and limited law enforcement[14,15]. Because VRUs carry a higher risk of severe injury when involved in RTCs, targeted interventions to enhance VRU safety have the potential to significantly reduce overall morbidity and mortality associated with RTCs[16].

Like many other cities in low-income countries, Moshi, Tanzania, has experienced a dramatic increase in road traffic that has exceeded the existing capacity of the city's traffic system. This increase in road traffic has presumably led to an increase in RTCs and RTIs. In one recent study, approximately two-thirds of traumatic brain injuries presenting for care at the local hospital were from RTIs[17]. In order to design effective strategies to reduce morbidity and mortality from RTIs in cities like Moshi across the developing world, more data is needed regarding regional epidemiology, underlying causative factors, and socioeconomic burdens of RTCs in these settings. Therefore, the aim of this study was to describe the epidemiology and geographic distribution of RTCs in Moshi, Tanzania.

Methods

Ethics

This retrospective data analysis was approved by the Duke University IRB (Pro00049408) and the Kilimanjaro Christian Medical Center Ethics Committee.

Setting

Moshi, Tanzania, is situated in northern Tanzania at the base of Mt. Kilimanjaro, and has a population of approximately 180,000 persons. The rainy season typically during the months of March and April, and outside of this period precipitation is minimal. There is one double-lane road within the city limits, and all other roads are single-lane roads. Roads are connected by traffic circles or intersections; there are no traffic lights in the city.

Data Set

Between February 2013 and January 2014, municipal police officers of Moshi, Tanzania recorded data regarding RTCs within the municipality of Moshi as part of a standard police reporting forms. Reported information included demographics of persons involved, collision location, and injuries sustained. Data were only recorded for RTCs that resulted in injuries. Data from these reports were entered into an online database using REDCap software (Vanderbilt University, Nashville, TN). Predictor data included latitude and longitude of the RTI, age of victim, gender, level of schooling, day of week, time of day, weather, type of road, vehicles involved, alcohol intoxication, and safety equipment used. Outcome data included severity of injury (grievous or non-grievous), whether or not there were any fatalities, and whether or not the patient was transported to a hospital. The determination of grievous versus non-grievous injury was made at the sole discretion by the reporting police officer; no standard definition was available. Geolocation coordinates were determined based on addresses and description in police data, or the latitude and longitude if available. These were used for further spatial analysis.

Data Analysis

Data were imported into Excel 2013 (Microsoft, Remond, WA) and JMP 12 (SAS Institute, Cary, NC). Descriptive data were analyzed with frequencies and proportions. Bivariate and multivariate association models were conducted with R Language for statistical programing, through chi-square, fisher's exact, and logistic regression models (the R foundation, Vienna, Austria). Missing data were analyzed individually. Age and gender information was missing for a large number of reports, and since there were non-random patterns of missing age and gender information, these variables were excluded from the models. Multiple imputation was conducted for the other variables in the dataset, through the mice package in R[18]. Variables with near zero variance were also excluded from the multivariate modeling. Type of vehicle was not included in the multivariate model because it was collinear with the presence of VRU.

To perform spatial analysis of RTCs in order to determine their distribution and identify possible hotspots, the kernel density estimator was used with heatmap plugin software Quantum GIS, version 2.4 Team[19]. This estimator is a two-dimensional function which weighs holes within a defined radius, indicating a higher or lower concentration of events analyzed[20]. A weighted measure was used to increase the influence of crash severity (non-grievous, grievous, fatal) on the resulting heatmap.

Results

Descriptive Statistics

Police reported 300 RTIs during the study period. Of these, 35 (12%) were considered grievous. Characteristics of RTI victims are summarized in Table 1. 121 (89%) of the persons injured in the reported RTCs were male, and the average victim age was 33 years old. Seatbelts were only worn by 64% of car victims and helmets were only worn by 43% of motorcycle victims. No grievous injuries were reported among those who wore helmets or seatbelts.

Detailed characteristics of the reported RTIs are summarized in Table 1. The majority of RTIs occurred during daylight hours (67%) and at locations where there was no form of traffic control (88%). VRUs were involved in 59% of RTIs during the study period. Cars (48%) and motorcycles (35%) were the most commonly involved vehicles. Alcohol testing was only performed in 72 (24%) of cases, and of these only 10 (14%) of drivers were found to be alcohol positive.

Association with injury severity

Bivariate association of victims and crashes characteristics with severity of injury showed that those who suffered grievous injuries tended to be older, more common when VRUs and, similarly, more frequent when motorcycles, buses and trucks were involved (Table 1). In the multivariate analysis, VRU (OR 5.34), Truck (OR 3.62) and Bus (OR 3.68) related crashes were associated with higher odds of grievous crashes (Table 2).

GIS Mapping

GIS maps of RTI hotspots are shown in Figures 2–4. The geospatial distribution of RTIs occurred predominantly at intersections of two main roads: Taifa Road and Mawenzi Road (Figures 2A and 2B). Taifa Road is a high-speed one lane road that connects Moshi to other surrounding cities. Mawenzi Road refers to the mostly populated area of Urban Moshi, involving more road traffic and VRUs.

Comparison of Figures 2A and 2B demonstrates that the same intersections where RTIs were most common were also the locations where grievous injuries and fatalities were most common. Figure 3A and 3B demonstrates similar geospatial distribution of RTIs involving cars and motorcycles, following the overall trend of hotspots (Taifa Road and Maweni Road). Trucks and buses had hotspots centered mostly in the intersection of Mawenzi Road and Market Street, a highly populated and traffic dense area of Urban Moshi (Figure 3C and 3D). Trucks also showed a hotspot in Taifa Road close to the Moshi Club, a higher speed road with low signs and structure (Figure 3C). Figure 4A and 4B displays the geospatial distribution of both grievous and non-grievous injuries in Moshi. The main discrepancy is that grievous/fatal injuries happened mostly on Mawenzi Road, both in a Urban neighborhood with local streets and commercial activity, and in the intersection with Market Road, an important traffic hub to other parts of Moshi.

Discussion

This is the first evaluation of the geospatial distribution, epidemiology, and risk factors for RTI in Tanzania, and of the most in-depth assessment in a midsized city in sub-saharan Africa. In this study setting, the involvement of vulnerable road users (motorcyclists, bicyclists, and pedestrians) was associated with a markedly elevated risk of increased injury severity, consistent with the findings of prior studies performed elsewhere in sub-Saharan Africa[21–23]. In the sequential bivariate analysis, several factors were found to be associated with decreased risk of grievous injury, including younger age of victim, use of helmets, and use of seatbelts. These findings are again consistent with the results of studies conducted elsewhere in sub-Saharan Africa[24–26].

Although alcohol positive, speeding and poor light conditions have been associated with increased risk of injury severity in studies performed in Ethiopia and Kenya[23,27], these factors were not associated with increased risk of grievous injury in this study. The reasons for this discrepancy are not clear, but could be a reflect of the overall lack of infra-structure of Tanzanian roads and the reporting method, which makes it harder to identify alcohol use, time of crash or driving behavior. Only 35% of all RTIs from this police data set were associated with motorcycle use. This is somewhat lower than local hospital-based data which demonstrates that 49% of road traffic crash victims who present for care of a traumatic brain injury were on a motorcycle[17]. This discrepancy may be due to underreporting of RTIs involving motorcycles, as motorcycle crashes have been shown to be subject to underreporting bias[28,29].

The geospatial analysis did identify hotspots for RTIs, suggesting that targeted interventions at these specific locations could result in significant reduction in RTIs in this setting. The vast majority of RTIs occurred in four limited areas of Taifa Road and Mawenzi Road, the two main corridors of Moshi. Built environment analysis would potentially help to understand the particular characteristics that predict the risk of a hotspot. For instance, one of the hotspots that is consistent across all types of motor vehicles and for grievous and non-grievous injuries it the intersection of Mawenzi Road and Market street. This specific intersection is complicated by the fact that it is right before a major round-about, so drivers entering this intersection are faced with a group of vehicles lined up waiting to enter the roundabout.

In addition to the overall RTI hotspot patterns, trucks and buses followed a disparate hotspot pattern. The bus and truck hotspots are more concentrated in the Moshi Urban area in high-traffic areas that may serve as commuter hubs while the motorcycle and car RTIs are spread throughout downtown Moshi. Additionally, trucks have a hotspot along Tafia road–a one lane high-speed road used to commute from Moshi Urban and to connect Moshi with other cities around. This specific hotspot is located in front o a bus and motorcycle stand in the road that could help to explain the higher risk for crashes. It is noteworthy that both Trucks and Buses related crashes had a higher odds of grievous injuries, in relation to other motor vehicle transportation, similar to results found in Ghana[9]. This results is particularly interesting because it draws attention to the unsafe usage of Buses and Trucks as transportation methods that require safety interventions and regulations on its own, but receive little attention from the literature.

These overall hotspot locations are the main sites where all types of injury occurred; minor, grievous and fatal crashes, and injuries associated with all types of vehicles. Minor injuries extend along the length of the road, while grievous and fatal injuries are more frequently seen at intersections, consistent with other literature on RTI distribution[9,30,31]. This location of grievous injuries overlaps with the location of truck and bus hotspots, supporting that trucks and buses had more grievous injuries than cars. A formal environmental analysis of these streets and their intersections may help to identify future interventions to reduce RTIs at these locations. It is likely that the installation of stoplights or speed humps near known hotspots may produce a significant reduction in morbidity and mortality from RTI by preventing excessive acceleration at these specific locations.

Although cost has been suggested as a major factor in the reduction of RTI morbidity and mortality, most interventions such as speed bumps, improved traffic signage, and traffic lights are affordable for governments to implement in comparison with the cost of RTI[10,32]. This police data provides specific locations which could be amenable to future environmental analysis for specific suggestions about road improvements. Similarly, this data suggests targeted interventions to protect VRUs such as bicycle lanes, helmet laws, and protected crosswalks are likely to significantly reduce rates of grievous injury.

In this study, none of the grievously injured car victims wore seatbelts and none of the grievously injured motorcycle victims wore helmets. While data regarding use of seatbelts and helmets was not available in many cases, none of the victims who had documented use of helmets or seatbelts were grievously injured. Overall, only 64% of car victims and 43% of motorcycle victims used seatbelts or helmets, respectively. These data are concerning and emphasize the importance of basic safety equipment and the urgent need to increase their use in Moshi. These findings are consistent with prior data from the region which shows that Moshi motorcycle taxi drivers have extremely low rates of safety equipment use[33]. There is ample data to support the effectiveness and cost effectiveness of the use of these and other safety equipment even in LMIC[10,34]. While the challenges of increasing safety equipment usage are immense, including availability of the equipment, laws supporting their use, and variable enforcement, further multifaceted approaches to increase use of safety equipment is needed.

There are several limitations of this study. First, this study involved a secondary analysis of the data collected by the Municipal Police of Moshi, Tanzania. Therefore, the RTIs analyzed in this study are limited to those which were reported to police and noted by officers. Traffic reports from those cases being processed by courts or insurance companies were not available. This situation may have introduced some bias as very minor injuries were likely not reported to police, while reports of very major injuries may be more likely to be unavailable due to court proceedings. It is uncertain whether missing data were truly non-random. Previous studies have shown under-reporting of RTIs to police in low and middle income countries[27,35], but to date there have been no quality assessments of the Moshi, Tanzania police data. Similarly, completeness of the police data was a challenge. More than half of the police reports did not have information on the age or gender of the injured party and 7% of the records did not include enough information in order to conduct geolocation for spatial analysis. This is unfortunately a very common challenge especially in low and middle income settings[36]. Furthermore, several important study variables including grievous versus non grievous injury, daylight versus dark conditions, and presence of traffic control was determined at the discretion of the reporting policy officer. Determination of what constituted a grievous injury, therefore, was subjective and may have varied from officer to officer. Despite these limitations, given the absence of data regarding RTI epidemiology in sub-Saharan Africa, and the absence of other RTI data sources in Moshi, this extensive police database represents an important first step in understanding and describing the characteristics and distribution of RTIs in the region.

Conclusion

In Moshi, Tanzania, RTIs occur in predictable locations near busy intersections and have identified hotspots that ought to the the focus of targeted traffic safety interventions. The involvement of vulnerable road users (motorcyclists, bicyclists, and pedestrians) was associated with increased injury severity. Basic safety equipment such as helmets and seatbelts were woefully underutilized. Although this study suggests several potential interventions for reducing RTI morbidity and mortality in Moshi, more comprehensive data collection mechanisms are needed across sub-Saharan Africa to allow for a more robust analysis of risk factors and distribution of RTIs.

Acknowledgments

We would like to thank the Moshi Police Department for their collaboration in this project as well as our KCMC Casualty Department Research Team.

Funding: This project was made possible by the Mentored Research Training Program in collaboration with the HRSA-funded KCMC MEPI grant # T84HA21123-02; U.S. National Institutes of Health and the Duke Division of Emergency Medicine. Dr. Staton would like to acknowledge salary support funding from the Fogarty International Center (Staton, K01 TW010000-01A1).

References

1. Global Road Safety Facility. Transport for Health: The Global Burden of Disease From Motorized Road Transport | Institute for Health Metrics and Evaluation. Seatle: 2014. Available at: http://www.healthdata.org/policy-report/transport-health-global-burden-disease-motorized-road-transport
2. World Health Organization. Fact sheets. WHO. Geneva: World Health Organization; 2015. Road traffic injuries. Available at: http://www.who.int/violence_injury_prevention/road_traffic/en/
3. Dalal K, Svanström L. Economic Burden of Disability Adjusted Life Years (DALYs) of Injuries. Health (Irvine Calif). 2015; 7(4):487–94. Available at: http://www.scirp.org/journal/PaperDownload.aspx?DOI=10.4236/health.2015.74058.
4. Mathers, CD., Loncar, D., Boreham, J., Thun, M., Heath, J., Doll, R. Samet, J., editor. Projections of Global Mortality and Burden of Disease from 2002 to 2030; PLoS Med. 2006. p. e442Available at: http://dx.plos.org/10.1371/journal.pmed.0030442
5. Patton GC, Coffey C, Sawyer SM, Viner RM, Haller DM, Bose K, et al. Global patterns of mortality in young people: a systematic analysis of population health data. 2009; 374:881–92.

www.thelancet.com. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.527.8988&rep=rep1&type=pdf.

6. Hofman K, Primack A, Keusch G, Hrynkow S. Addressing the growing burden of trauma and injury in low- and middle-income countries. Am J Public Health. 2005; 95(1):13–7. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15623852. [PubMed: 15623852]
7. World Health Organization. Violence and Injury Prevention: Global status report on road safety. Vol. 2015. WHO. Geneva: World Health Organization; 2015. http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/
8. Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N., Meijers. Smart Cities - Ranking of European medium-sized cities. Viena: 2007. Available at: http://ign.ku.dk/ansatte/ign-ansatte/?pure=files/37640170/smart_cities_final_report.pdf
9. Afukaar FK. Speed control in developing countries: issues, challenges and opportunities in reducing road traffic injuries. Inj Control Saf Promot. 2003; 10(1–2):77–81. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12772489. [PubMed: 12772489]
10. Waters HR, Hyder AA, Phillips TL. Economic Evaluation of Interventions to Reduce Road Traffic injuries - A Review of the Literature with Applications to Low and Middie-income Countries. Asia Pacific J Public Health. 2004; 16(1):23–31. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18839864.
11. Gosselin RA, Spiegel DA, Coughlin R, Zirkle LG. Injuries: the neglected burden in developing countries. Bull World Health Organ. 2009; 87(4):246–246a. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19551225. [PubMed: 19551225]
12. Agbonkhese, O., Yisa, G., Agbonkhese, E., Akanbi, D., Aka, E., Mondigha, E. Civil and Environmental Research. Vol. 3 Civil and Environmental Research. International Institute for Science, Technology and Education (IISTE); 2011. p. 90-99.Available at: http://www.iiste.org/Journals/index.php/CER/article/view/9369
13. Naci H, Chisholm D, Baker TD. Distribution of road traffic deaths by road user group: a global comparison. Inj Prev. 2009; 15(1):55–9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19190278. [PubMed: 19190278]
14. Edirisinghe PAS, Kitulwatte IDG, Senarathne UD. Injuries in the vulnerable road user fatalities; a study from Sri Lanka. J Forensic Leg Med. 2014; 27:9–12. Available at: http://www.sciencedirect.com/science/article/pii/S1752928X14001255. [PubMed: 25287792]
15. Chandran A, Sousa TRV, Guo Y, Bishai D, Pechansky F, The Vida No Transito Evaluation Tea. Road Traffic Deaths in Brazil: Rising Trends in Pedestrian and Motorcycle Occupant Deaths. Traffic Inj Prev. 2012; 13(sup1):11–6. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22414123. [PubMed: 22414123]
16. Constant A, Lagarde E, Carberry T, Suffla S, Ratele K. Protecting Vulnerable Road Users from Injury. PLoS Med. 2010; 7(3):e1000228. Available at: http://dx.plos.org/10.1371/journal.pmed.1000228. [PubMed: 20361017]
17. Staton CA, Msilanga D, Kiwango G, Vissoci JR, de Andrade L, Lester R, et al. A prospective registry evaluating the epidemiology and clinical care of traumatic brain injury patients presenting to a regional referral hospital in Moshi, Tanzania: challenges and the way forward. Int J Inj Contr Saf Promot. 2017; 24(1):69–77. Available at: http://www.ncbi.nlm.nih.gov/pubmed/26239625. [PubMed: 26239625]
18. van Buuren, S. Title Multivariate Imputation by Chained Equations; Package “mice”. 2017. p. 139Available at: http://www.stefvanbuuren.nl
19. Anselin L, Syabri IKY. GeoDa: an introduction to spatial data analysis. Geogr Anal. 2006; 38(5):22.
20. Waller, LA., Gotway, CA. Applied spatial statistics for public health data. John Wiley & Sons; 2004. p. 494
21. McGreevy J, Stevens KA, Ekeke Monono M, Etoundi Mballa GA, Kouo Ngamby M, Hyder AA, et al. Road traffic injuries in Yaoundé, Cameroon: A hospital-based pilot surveillance study. Injury. 2014; 45(11):1687–92. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24998038. [PubMed: 24998038]

22. Bhatti JA, Sobngwi-Tambekou J, Lagarde E, Salmi L-R. Situational factors associated with road traffic crashes: A case–control study on the Yaoundé–Douala road section, Cameroon. Int J Inj Contr Saf Promot. 2010; 17(4):215–22. Available at: http://www.tandfonline.com/doi/abs/10.1080/17457301003728510. [PubMed: 20352551]
23. Mogaka EO, Ng'ang'a Z, Oundo J, Omolo J, Luman E. Factors associated with severity of road traffic injuries, Thika, Kenya. Pan Afr Med J. 2011; 8:20. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22121429. [PubMed: 22121429]
24. Boniface R, Museru L, Kiloloma O, Munthali V. Factors associated with road traffic injuries in Tanzania. Pan Afr Med J. 2016; 23:46. Available at: http://www.ncbi.nlm.nih.gov/pubmed/27217872. [PubMed: 27217872]
25. Seid M, Azazh A, Enquselassie F, Yisma E. Injury characteristics and outcome of road traffic accident among victims at Adult Emergency Department of Tikur Anbessa specialized hospital, Addis Ababa, Ethiopia: a prospective hospital based study. BMC Emerg Med. 2015; 15(1):10. Available at: http://www.ncbi.nlm.nih.gov/pubmed/25990560. [PubMed: 25990560]
26. Chalya PL, Mabula JB, Dass RM, Mbelenge N, Ngayomela IH, Chandika AB, et al. Injury characteristics and outcome of road traffic crash victims at Bugando Medical Centre in Northwestern Tanzania. J Trauma Manag Outcomes. 2012; 6(1):1. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22321248. [PubMed: 22321248]
27. Abegaz, T., Berhane, Y., Worku, A., Assrat, A., Assefa, A. Helleringer, S., editor. Road Traffic Deaths and Injuries Are Under-Reported in Ethiopia: A Capture-Recapture Method; PLoS One. 2014 Jul 23. p. e103001Available at: http://www.ncbi.nlm.nih.gov/pubmed/25054440
28. Janstrup KH, Kaplan S, Hels T, Lauritsen J, Prato CG. Understanding traffic crash under-reporting: Linking police and medical records to individual and crash characteristics. Traffic Inj Prev. 2016; 17(6):580–4. Available at: http://www.ncbi.nlm.nih.gov/pubmed/26786061. [PubMed: 26786061]
29. Watson A, Watson B, Vallmuur K. Estimating under-reporting of road crash injuries to police using multiple linked data collections. Accid Anal Prev. 2015; 83:18–25. Available at: http://www.ncbi.nlm.nih.gov/pubmed/26162640. [PubMed: 26162640]
30. Razzak JA, Khan UR, Jalal S. Application of geographical information system (GIS) for mapping road traffic injuries using existing source of data in Karachi, Pakistan–a pilot study. J Pak Med Assoc. 2011; 61(7):640–3. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22204236. [PubMed: 22204236]
31. Hyder AA, Ghavar A, Masood TI. Motor vehicle crashes in Pakistan: the emerging epidemic. Inj Prev. 2000; 6:199–202. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1730645/pdf/v006p00199.pdf. [PubMed: 11003185]
32. Onywera VO, Blanchard C. Road accidents: a third burden of "disease" in sub-Saharan Africa. Glob Health Promot. 2013; 20(4):52–5. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24469303. [PubMed: 24469303]
33. Sumner SA, Pallangyo AJ, Reddy EA, Maro V, Pence BW, Lynch C, et al. Effect of free distribution of safety equipment on usage among motorcycle–taxi drivers in Tanzania—A cluster randomised controlled trial. Injury. 2014; 45(11):1681–6. Available at: http://www.sciencedirect.com/science/article/pii/S0020138314002010. [PubMed: 24861418]
34. Forjuoh SN. Traffic-related injury prevention interventions for low-income countries. Inj Control Saf Promot. 2003; 10(1–2):109–18. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12772494. [PubMed: 12772494]
35. Periyasamy N, Lynch CA, Dharmaratne SD, Nugegoda D, Ostbye T. Under reporting of road traffic injuries in the district of Kandy, Sri Lanka. BMJ Open. 2013; 3(11):e003640. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24213095.
36. Mock C, Quansah R, Goosen J, Kobusingye O. Trauma care in Africa: The way forward. African J Trauma. 2014; 3(1):3. Available at: http://www.abc.com/text.asp?2014/3/1/3/139448.

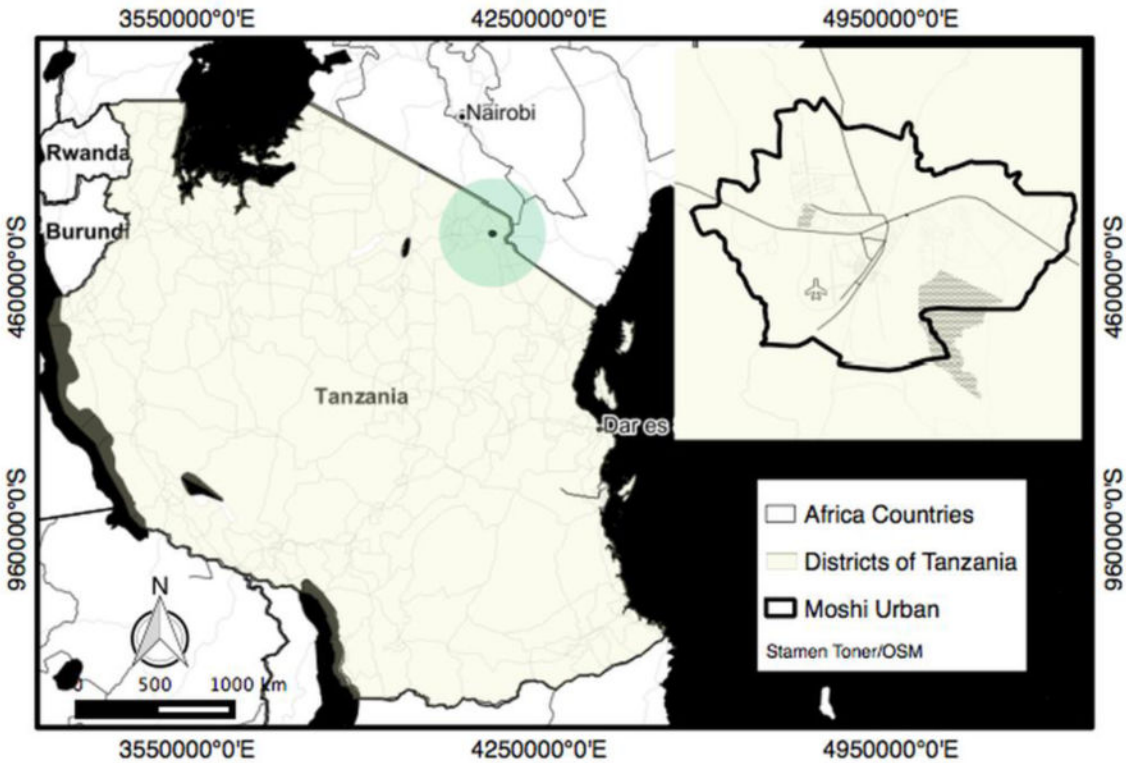

Figure 1.
Geographical location of Moshi Urban - Tanzania. Source: QGIS OSM plugin (http://qgis.org/en/site/)

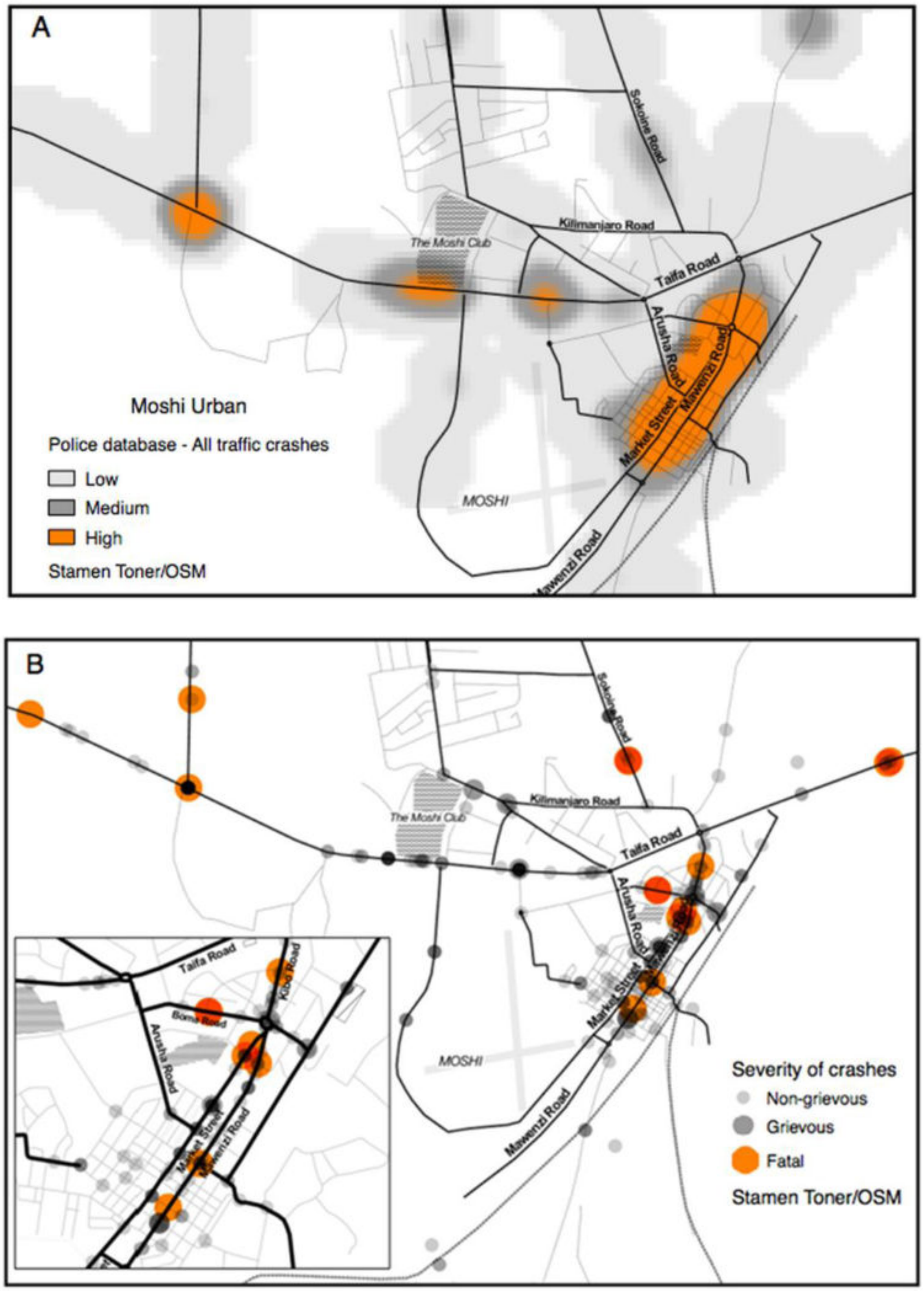

Figure 2.

Police Data Crashes depicted by A) Kernel Density Analysis of High, Medium and Low Density areas of All Types of Road Traffic Crashes, B) Locations by Severity of Crash.

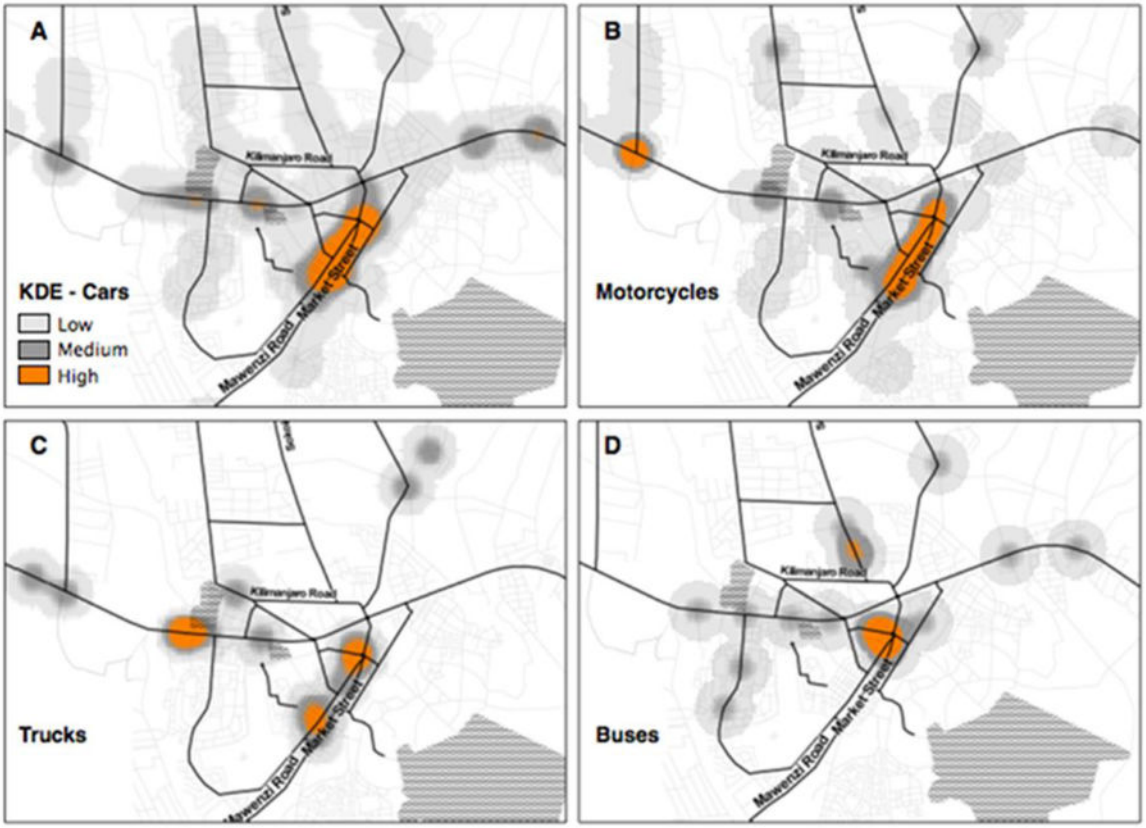

Figure 3.
A–D: Comparison of the Kernel Density Estimation of Low, Medium and High Density Hotspots of A) Cars, B) Motorcycles, C) Trucks, D) Buses.

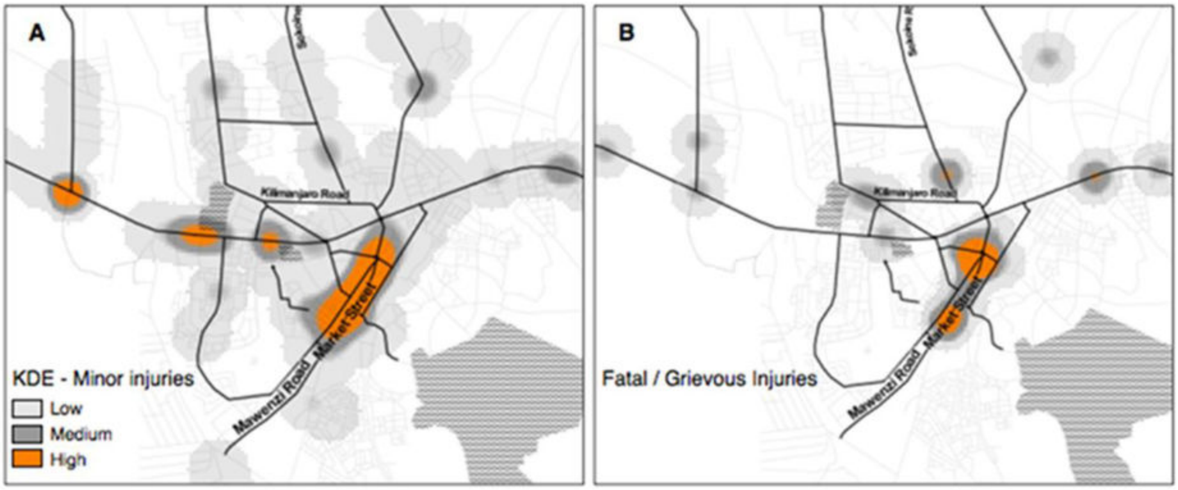

Figure 4.
A–B: Hotspots of Crashes by A) Minor Injuries B) Fatal/Grievous Injuries

Table 1

Characteristics of persons injured in RTCs in Moshi, Tanzania.

Characteristic (N=300)	Total	Grievous (N=35)	Non-Grievous (N=264)	P-value
Age (years) (N=131), Mean (sd)	33.13 (13.94)	42.04 (17.44)	31.03 (12.16)	0.001 *
Male (N=136), N (%)	121 (88.97)	22 (81.48)	99 (90.82)	0.291
Type of victim (N=199), N (%)				
Driver	136 (68.34)	20 (68.97)	116 (68.23)	0.969
Passenger	16 (8.04)	2 (6.89)	14 (8.24)	
Pedestrian	47 (23.62)	7 (24.14)	40 (23.53)	
Seatbelt if car victim (N=25), N(%)	16 (64.00)	0 (–)	16 (64.00)	–
Helmet use if on motorcycle (N=49), N(%)	21 (42.86)	0 (0.00)	21 (48.84)	–
Light condition (N=299), N (%)				
Daylight	201 (67.00)	23 (65.71)	177 (67.04)	0.875
Darkness	99 (33.00)	12 (34.29)	87 (32.96)	
Day of the week (N=300), N (%)				
Sunday	42 (14.00)	3 (8.57)	39 (14.77)	0.656
Monday	36 (12.00)	3 (8.57)	33 (12.50)	
Tuesday	43 (14.33)	4 (11.43)	38 (14.39)	
Wednesday	39 (13.00)	6 (17.14)	33 (12.50)	
Thursday	47 (15.67)	6 (17.14)	41 (15.53)	
Friday	43 (14.33)	4 (11.42)	39 (14.77)	
Saturday	50 (16.67)	9 (25.71)	41 (15.53)	
Holiday/Weekend (N=300), N (%)	102 (34.00)	13 (37.14)	89 (33.71)	0.832
Involving VRU (N=294), N (%)	175 (59.52)	30 (85.71)	144 (55.81)	0.001 *
Straight Stretch of roads (N=295), N (%)	210 (71.19)	20 (60.61)	189 (72.41)	0.228
Traffic control (N=300), N (%)				
No control	266 (88.67)	35 (100.00)	230 (87.12)	
Police/Warden	14 (4.67)	0 (0.00)	14 (5.30)	
Signs	20 (6.66)	0 (0.00)	20 (7.58)	
Type of vehicle (N=296), N (%)				
Bus	22 (7.43)	5 (14.71)	17 (6.51)	0.015 *
Car	142 (47.97)	9 (26.47)	133 (50.96)	
Motorcycle	104 (35.13)	14 (41.18)	90 (34.48)	
Truck	24 (8.11)	5 (14.71)	19 (7.28)	
Other	4 (1.35)	1 (2.94)	2 (7.28)	
Tested for alcohol (N=299), N (%)	72 (24.08)	4 (11.43)	67 (25.48)	0.105
Alcohol positive (N=72), N (%)	10 (13.89)	1 (25.00)	9 (13.43)	0.463
Presence of speed limit (N=297), N (%)	127 (42.8)	17 (51.5)	109 (41.5)	0.359
Speeding and/or aggressive driving (N=289), N (%)	226 (78.20)	31 (88.57)	195 (77.07)	0.091

*Significant at $p<0.05$;

t-tests were used for numeric data and chi-square for categorical data, with fisher's exact correction when applicable.

Table 2

Association of RTCs environmental and drivers characteristics and severity (Grievous vs. Non-Grievous) of the crash.

	OR	(CI 95%)	P-value
Dark vs. Daylight condition	1.03	(0.48;2.28)	0.937
VRU crash vs. non-VRU crash	5.34	(2.09;16.65)	0.001 *
Truck crash vs. non-Truck crash	3.62	(1.01;11.82)	0.037 *
Bus crash vs. non-Bus crash	3.69	(1.15;10.94)	0.021 *
Stretch of road vs. Junctions	1.26	(0.57;2.71)	0.562
Speeding and/or aggressive driving	2.30	(0.82;8.28)	0.148
Alcohol testing being performed	0.42	(0.12;1.16)	0.125

OR = Odds ratio; CI = Confidence interval; VRU = Vulnerable road users

*P-value > 0.05