OPEN ACCESS Freely available online

PLOS ONE

Road Traffic Deaths and Injuries Are Under-Reported in Ethiopia: A Capture-Recapture Method

Teferi Abegaz[1]*, Yemane Berhane[2], Alemayehu Worku[3], Abebe Assrat[4], Abebayehu Assefa[5]

1 School of Public and Environmental Health, College of Medicine and Health Sciences, Hawassa University, Hawassa, Ethiopia, **2** Addis Continental Institute of Public Health, Addis Ababa, Ethiopia, **3** School of Public Health, College of Health Sciences, Addis Ababa University, Addis Ababa, Ethiopia, **4** Ministry of Transport, Addis Ababa, Ethiopia, **5** World Health Organization (WHO) Ethiopia, Addis Ababa, Ethiopia

Abstract

In low and middle income countries road traffic injuries are commonly under-reported. This problem is significantly higher among those less severely injured road users. The objective of this study was to determine the incidence and the level of ascertainment of road traffic injuries and deaths by traffic police and hospital registry. In this study two-sample capture-recapture method was applied using data from traffic police and hospital injury surveillance, through June 2012 to May 2013. The study was conducted on one of the busiest highways in Ethiopia, the Addis Ababa – Hawassa highway. Primary data were collected by accident investigators and hospital emergency nurses using a structured checklist. Four matching variables; name of the victim, sex, place and time of the accidents was used to get the matched cases. During the study period the police independently reported 224 deaths and 446 injuries/billion vehicle kilometer while hospitals reported 123 deaths and 1,046 injuries/billion vehicle kilometer. Both sources in common captured 73 deaths and 248 injuries/billion vehicle kilometer. Taking the two data sources into consideration, the capture-recapture model estimated the incidence of deaths and injuries ranged 368–390 and 1,869–1,895 per billion vehicle kilometer, respectively. The police source captured 57.4%–60.9% of deaths and 23.5%–23.9% of injuries while the hospital sources captured 31.5%–33.4% of deaths and 55.2%–56% of injuries. Deaths and injuries among females, younger age victims, cyclists/motorcyclists and pedestrians were under-reported by traffic police. In conclusion neither of the two sources independently provided accurate coverage of road traffic incident related deaths and injuries. Strengthening both systems is necessary to obtain accurate information on road accidents and human causalities.

Citation: Abegaz T, Berhane Y, Worku A, Assrat A, Assefa A (2014) Road Traffic Deaths and Injuries Are Under-Reported in Ethiopia: A Capture-Recapture Method. PLoS ONE 9(7): e103001. doi:10.1371/journal.pone.0103001

Editor: Stephane Helleringer, Columbia University, United States of America

Received February 14, 2014; **Accepted** June 25, 2014; **Published** July 23, 2014

Funding: The sources of the fund for this study are Hawassa University and World Health Organization, Ethiopia (Grant number: AFETH1206929). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The only involvement in this study by these two organizations are: Follow the researcher to utilize the allocated funds properly based on the financial specification submitted in the document and finally receive the output of the research and the financial statement.

Competing Interests: The authors have declared that no competing interests exist.

* Email: teferiabegaz@gmail.com

Introduction

Road traffic incidents pose enormous challenges. Globally 1.3 million fatal and up to 50 million non-fatal injuries are reported [1]. It is the second most common cause of death among the most economically active population group (15–44 year-old) [2]. Low income countries with small numbers of vehicles experience a huge burden of fatalities [3–5]. Ethiopia, according to WHO report, is considered one of the worst countries in the world where road transportation kills and injures a large number of road users every year [6].

Estimates of the magnitude of road traffic incident and traffic injuries in low-income countries are primarily obtained from police records and sometimes hospital registry data. However, both sources are affected by under reporting [7–9]. In Ethiopia, traffic police reports are the official source of data for road-related incidents. There is no established trauma care and registry, the health management information system (HMIS) reports traffic incident causalities as a soft tissue injury.

Researchers consistently indicate that high level of under-reporting of injuries and fatalities is observed, particularly in law and middle income countries, when the estimate is based on official records [10]. The problem of under- reporting is substantially higher for the nonfatal injury cases and vulnerable groups of road users (pedestrians, pedal cyclists, and motorcyclists) [7,11].

Capture-recapture approach provides estimates of the outcome of an event based on cases commonly captured by different data sources [12]. Originally the capture-recapture method was developed to estimate wild life populations [13]. However, in recent years, it has been commonly utilized in various epidemiological studies [14–16]; in determining infectious and non-infectious diseases [17,18]; and to estimate the incidence of road traffic incident causalities [19,20].

In low- and middle-income countries knowledge gap jeopardise resource allocation, even though cost effective interventions exist [21]. Few research has been conducted in low- and middle-income countries having poor data registry and high level of under-reporting [10,11]. There was no similar study conducted in Ethiopia. Therefore the objective of this study was to estimate the number of fatal and non-fatal injuries using a capture-recapture approach based on police and hospital data sources.

Method

Study setting

This study was conducted from June 2012 to May 2013, on one of the busiest highways of Ethiopia, the Addis Ababa - Hawassa highway. It is a two-way and two-lane road with an average width of 8 meters covering a distance of 264 Kilometers. The first 64 kilometers are part of the main route of the country's import and export corridor from the port of Djibouti. According to the information obtained from the Ethiopian Road Authority this road network is divided into four segments depending on the average daily vehicle flow. The higher traffic volume (more than 20,000 vehicles) observed near Addis Ababa city and subsequently decreased to 3,000 when it approaches to Hawassa city (Table 1).

Data sources

Hospital data source. The health management and information system (HMIS) report in Ethiopia is incomplete in some of the basic information used to run capture-recapture analysis. Hence, we conducted injury surveillance in five governmental hospitals found across the stretches of the studied highway (Bishoftu referral hospital, Adama referral hospital, Zeway Sher-Ethiopia hospital, Shashemene referral hospital and Hawassa referral teaching hospital). Data were recorded on a structured checklist prepared for the purpose of this study using five trained nurses working in the emergency department. Moreover, two senior emergency nurses and the principal investigator were involved as a supervisor. All injuries and deaths occurred on the studied road network were included. Relevant information of the name of the victim, age, sex, place and time of injury, type of road users and collision were recorded. Fatally injured cases in hospitals included dead on arrival and died prior to discharge or transfer.

Traffic data source. Traffic data were collected by sixteen trained road crash investigators working across the stretches of the highway. Furthermore, two senior police officers and the principal investigator were involved as a supervisor. A structured checklist was prepared and relevant information was collected at the scene of the incidents and followed the victims up to a month to get the final injury outcome. Fatalities include death at the scene of the incident and within one month of the incident. Information on the name of the victim, age, sex, injury severity, road user type, vehicle type, time and place of the incident and other relevant information were gathered.

Matching criteria

Casualties obtained from police and hospital sources were matched using four key identifier variables; name of the victim, gender, place and date of the crashes. Matched cases were considered if the victims shared at least three of the key identifier variables. For crash location matching, data collectors have sufficient information on the studied road network. Overlapping cases were coded "1" and non-overlapping cases as "0". Record-linkage was performed manually and after completing the linkage process, we entered the data using Epi-data 3.1 software.

Data analysis

Descriptive analysis was done using SPSS version 16 and by using a manual calculator. Ascertainment corrected incidence of deaths and injuries and the completeness of traffic and hospital data sources were determined by capture- recapture method using Chapman estimator [22]. This estimator is less affected by zeros and is said to be less biased than the Lincoln–Petersen estimator [23], and given by:

$$\hat{N} = \frac{(Nt+1) * (Nh+1)}{(n+1)} - 1$$

Where N_t and N_h are the numbers of people in traffic and hospital captures respectively, and n is the number of people identified in both sources (matches). The following formulas were used to calculate the standard error of the estimates (SE), and confidence interval of the estimates (95% CI):

$$SE(\hat{N}) = \sqrt{\frac{(\hat{N}-Nt)(\hat{N}-Nh)}{n}}$$

$$95\%\mathrm{CI} = \hat{N} \pm 1.96\mathrm{SE}$$

Stratified Capture-recapture analysis. Homogeneous reporting probability among hospital and police data were checked by using Chi-squared tests for the following factors: gender (male, female); age (<15, 15–44, 45–64 and ≥65); road user type (driver, passenger, pedestrian and bicyclist/motorcyclist); and collision type (with other vehicles, rollover, pedestrian collision and others). A stratified capture-recapture analysis was done for each of these factors on the subgroups, and summing the subgroup results to obtain an overall estimate.

Incidence rate calculation. Incidence of road traffic deaths and injuries were calculated using vehicle kilometer travel as a denominator. Information on the vehicle kilometer travel on the studied road network was obtained from the Ethiopian Road Authority Official website. The incidence rate was estimated using the following formula:

Table 1. Summary of distance, daily average vehicle flow and vehicle kilometer travel by road segments of the studied road, Addis Ababa- Hawassa, 2012.

Road segment	Distance in kilometer	Daily average vehicle flow	Vehicle kilometres travel
Dukem to Debre Zeit	13	21,913	284,869
Debre Zeit to Adama	51	17,496	892,296
Mojo to Shashemene	180	3,534	636,120
Shashemene to Hawassa	20	3,077	61,540
Total			**1,874,825**

doi:10.1371/journal.pone.0103001.t001

Table 2. Stratified capture-recapture estimates of deaths on the Addis Ababa- Hawassa highway, Ethiopia, June 2012–May 2013.

Stratified by		Number of unmatched in police data	Number of unmatched in hospital data	Number of matches	Est. Number of deaths (95% CI)	Est. Incidence (95% CI) Per billion vehicle kilometres
	Total	153	84	50	256(219–293)	374(329–419)
Gender	Male	122	61	43	172(150–194)	
	Female	31	23	7	95(45–145)	
	Total	153	84	50	267(227–307)	390(342–438)
Age	<15	20	7	4	33(15–51)	
	15–44	109	64	38	182(153–211)	
	45–64	18	10	6	29(9–49)	
	>65	6	3	2	8(4–12)	
	Total	153	84	50	252(216–288)	368(325–411)
Road user type	Driver	5	3	3	5(5–5)	
	Occupant	63	33	22	94(76–112)	
	Pedestrian	84	45	25	149(117–181)	
	Bicycle/motorcycle rider	1	3	0	8(−)	
	Total	153	84	50	256(219–293)	374(329–419)
Collision type	With other vehicle	56	33	17	107(70–144)	
	Rollover	23	10	7	32(25–39)	
	Pedestrian	71	36	24	106(86–126)	
	Others	3	5	2	7(3–11)	
	Total	153	84	50	252(216–288)	368(325–411)

doi:10.1371/journal.pone.0103001.t002

$$Incidencerate(R) = \frac{C}{V * 365 * L} * 1{,}000{,}000{,}000$$

Where: C stands for the total number of deaths or injuries; V is average daily traffic volume on the road segment; 365 stands for the number of days in a year and L is the average length travelled in kilometer. So the result interpreted as total number of death or injuries per billion vehicle kilometer travel on the studied road. According to International Traffic Safety Data and Analysis Group (IRTAD) report expressing deaths and injuries per vehicle kilo-meter travel is the most objective indicator to describe risk on the road network [24].

Ethical approval

We obtained ethical approval from Hawassa University College of Medicine and Health Science Ethical Review Committee. Written permission was obtained from hospitals and traffic police administrators. In addition, informed verbal consent was obtained from all study participants/caregivers and recorded by the research team on the ethical consent form (with prior approval obtained from our ethics review committee). Written consent was not suggested by Hawassa University College of Medicine and Health Science Ethical Review Committee. After completing the matching process the participants' names were deleted from the database to ensure confidentiality.

Results

In this study traffic police identified 153 deaths and 305 injuries, while hospital surveillance captured 84 deaths and 716 injuries. Table 2 and 3 illustrates the distribution of road traffic crash related deaths and injuries with regard to various characteristics. In both data sources males and 15–44 year-old age group accounted for the highest percentage of fatal and non-fatal cases. Males were killed and injured 3 times more often than females. Similarly, 71% and 75.6% deaths and 83.9% and 79.6% injuries were in the age range of 15–44 years-old in traffic police and hospitals registry, respectively.

The result showed that in the traffic data there is a statistical significant under-reporting of deaths and injuries among bicycle/motorcycle riders (0.6% and 1.3%, respectively), compared to hospital data (3.5% and 5.5%, respectively). Females, younger age victims and pedestrians were also under-estimated by the traffic data.

Traffic police independently reported 224 deaths and 446 injuries/billion vehicle kilometre, while hospitals reported 123 deaths and 1,046 injuries/billion vehicle kilometer. Both sources in common captured 73 deaths and 248 injuries/billion vehicle kilometer. Taking the two data sources into consideration, stratified capture-recapture analysis provide the incidence of deaths and injuries ranged 368–390 and 1,869–1,895 per billion vehicle kilometer, respectively (Table 2 and 3). Level of under-reporting was higher in both data sources; the police source captured 57.4%–60.9% of deaths and 23.5%–23.9% of injuries while the hospital sources captured 31.5%–33.4% of deaths and 55.2%–56% of injuries.

Discussion

This study illustrates the usefulness of the capture-recapture method to assess the completeness of official data sources. The

Table 3. Stratified capture-recapture estimates of injuries on the Addis Ababa- Hawassa highway, Ethiopia, June 2012–May 2013.

Stratified by		Number of unmatched in police data	Number of unmatched in hospital data	Number of matches	Est. Number of injuries (95% CI)	Est. Incidence (95% CI) Per billion vehicle kilometres
	Total	305	716	170	1,282(1,170–1,394)	1,873(1,738–2,008)
Gender	Male	226	515	125	929(835–1,023)	
	Female	79	201	45	350(291–409)	
	Total	305	716	170	1,279(1,168–1,390)	1,869(1,734–2,004)
Age	<15	17	80	18	76(−)	
	15–44	256	570	131	1,111(995–1,227)	
	45–64	29	54	18	86(76–96)	
	>65	3	12	3	12(12–12)	
	Total	305	716	170	1,285(1,173–1,397)	1,877(1,741–2,013)
Road user type	Driver	14	85	14	85(85–85)	
	Occupant	214	337	83	864(738–990)	
	Pedestrian	74	255	72	262(254–270)	
	Bicycle/motorcycle rider	3	39	1	79(−)	
	Total	305	716	170	1,290(1,177–1,403)	1,885(1,748–2,022)
Collision type	With other vehicle	116	190	47	465(377–553)	
	Rollover	109	204	36	538(415–661)	
	Pedestrian	74	263	73	267(261–273)	
	Others	6	59	14	27(−)	
	Total	305	716	170	1,297(1,183–1,411)	1,895(1,757–2033)

doi:10.1371/journal.pone.0103001.t003

analysis showed that the rate of ascertainment by police records and hospital surveillance were incomplete. Road traffic incident deaths and injuries were significantly under-reported by traffic police and hospitals. Police records preferentially reported deaths, while hospital records preferentially reported injuries. The results found in this study are consistent with previous research, in low-income countries traffic police data are more reliable for fatal injuries than hospital data, but for non-fatal injuries, hospital data capture more cases than do police records [9,12,25,26].

Low death reporting by hospitals may be explained by poor community awareness on the importance of medical evidence, particularly when the crash occurred in rural areas [7]. On the other hand, the transportation cost of the body to a health facility and back to the village could be also another challenge, especially if the incident happened on rural road and if the victims were pedestrians [12]. The higher rate of under reporting of the non-fatal injury cases by traffic police may be explained by such types of injuries usually took place near built-up areas, so victims could have been transported by families or bystanders directly to a hospital, without waiting the police [27,28]. Bicyclist and motorcycle riders are significantly underreported by traffic police sources, consistence with previous studies [7,28]. In addition, pedestrians were also under reported by the police registry. This can be explained by such types of road users usually belong to poor socioeconomic group, so they negotiate with the drivers and settle the issue without police involvement.

For a capture-recapture estimate to be valid at least the following four assumptions should be respected [29]. The first assumption is that the population should be closed. This assumption may not be a serious concern; since there is very little delay between the police attending the crash scene and the casualty's visit to the hospital: at most a few days for the most slightly injured casualties [30]. The second assumption is sources are independent, (i.e., reporting to one source does not influence the chance of the event being reported to the other source). This assumption is the most difficult to attain in capture-recapture study [12]. Researchers recommended that using three or more sources to control the effect of independency [31,32]. However, we couldn't do this because of data inaccessibility. We believe some positive dependencies in this regard, since it is a medico-legal issue, especially for serious and fatal cases. Police need medical evidence from hospitals to bring the issue to the court. As a result the ascertainment corrected number will be underestimated. Therefore, the obtained estimates of the total number of casualties must be interpreted as lower bounds [33]. The third assumption is about homogeneous reporting probability. To deal with this using stratification analysis is recommended [30,33]. So in this study stratified analysis was done using selected road users characteristics like; gender, age of the victim and road user type. The fourth assumption is that the capture history of all cases should be accurate, and sufficient information must be available in each source. Thus we collected primary data using active surveillance from police and hospitals, the information bias related to inaccurate recording would be minimal.

One of the potential challenges to apply capture- recapture method is the lack of comprehensive data recording system, especially by health institution. One possible solution is to revise the hospital HMIS by including necessary information on the injured cases, particularly the place, time and cause of the injury so

as easily calculated by capture recapture method with other official sources.

In conclusion neither of the two sources independently provided accurate coverage of road traffic incident related deaths and injuries. Strengthening both systems is necessary to obtain accurate information on road incident and human causalities.

Acknowledgments

We would like to thank Hawassa University and Addis Continental Institute of Public health for this research opportunity. The Authors are grateful to management bodies and police officers involved in the data collection process.

Author Contributions

Conceived and designed the experiments: TA YB AW A. Assrat A. Assefa. Performed the experiments: TA. Analyzed the data: TA. Wrote the paper: TA YB AW A. Assrat A. Assefa. Assisting the experiments: YB AW. Principal investigator: TA.

References

1. Sleet D, Baldwin G, Dellinger A, Dinh-Zarr B (2011) The Decade of Action for Global Road Safety. Journal of Safety Research 42: 147–148.
2. World Health Organization (2008) The Global Burden of Disease: 2004 update. World Health Organization Geneva.
3. Mohan D (2002) Road safety in less-motorized environments: Future concerns. Int J Epidemiol 31: 527–532.
4. Nantulya VM, Reich MR (2002) The neglected epidemic: Road traffic injuries in developing countries. BMJ 324: 1139–1141.
5. Ameratunga S, Hijar M, Norton R (2006) Road-traffic injuries: Confronting disparities to address a global-health problem. Lancet 367: 1533–1540.
6. World Health Organization (2009) Global status report on road safety: time for action. World Health Organization Geneva.
7. Peden M, Scurfiled R, Sleet D, Mohan D, Hyder A, et al. (2004) World report on road traffic injury prevention. Geneva: World Health Organization.
8. Sasser S, Varghese M, Kellermann A, Lormand J (2005) Prehospital trauma care systems. Geneva: World Health Organization.
9. Tercero F, Andersson R, Peña R, Svanström L (1998) Can valid and prevention-oriented information on injury occurrence be obtained from existing data sources in developing countries? An example from Nicaragua. International Journal of Consumer Product Safety 5: 99–105.
10. Samuel JC, Sankhulani E, Qureshi JS, Baloyi P, Thupi C, et al. (2012) Under-Reporting of Road Traffic Mortality in Developing Countries: Application of a Capture-Recapture Statistical Model to Refine Mortality Estimates. PloS ONE 7: e31091.
11. HungTrinhVan, Singhasivanon P, Kaewkungwal J, Suriyawongpaisal P, Khai LH (2006) Estimation of non-fatal road traffic injuries in Thai Nguyen, Vietnam using capture-recapture method. Southeast Asian J Trop Med Public Health 37: 405–411.
12. Tercero F, Andersson R (2004) Measuring transport injuries in a developing country: an application of the capture-recapture method. Accident Analysis and Prevention 36: 13–20.
13. Pollock K (1991) Modeling capture, recapture and removal statistics for estimation of demographic parameters for rish and wildlife populations. J Amer Stat Assn 86: 225–238.
14. Laure V, Stéphane L (2008) Capture-recapture estimates of the local prevalence of problem drug use in six French cities. European Journal of Public Health 19: 32–37.
15. Rongsheng L, Boheng L, Ping Y, Li F, Yong H, et al. (2005) A study on capture-recapture method for estimating the population size of injecting drug users in South West China. Journal of Health Science 5: 405–409.
16. Brugha RF, Swan AV, Hayhurst GK, Fallon MP (1998) A drug misuser prevalence study in a rural English district. European Journal of Public Health 8: 34–36.
17. Sekikawa A, Eguchi H, Tominaga M, Manaka H, Sadaki H, et al. (1999) Evaluating the reported prevalence of type-2 diabetes mellitus by the Oguni diabetes registry using a two-sample method of capture-recapture. International Journal of Epidemiology 28: 498–501.
18. Tilling K, Sterne JA, Wolfe CD (2001) Estimation of the incidence of stroke using a capture-recapture model including covariates. International Journal of Epidemiology 30: 1351–1359.
19. Zavareh DK, Mohammadi R, Laflamme L, Naghavid M, Zareie A, et al. (2008) Estimating road traffic mortality more accurately: use of the capture - recapture method in the West Azarbaijan Province of Iran. International Journal of Injury Control and Safety Promotion 15: 9–17.
20. Morrison A, Stone DH (2000) Capture-recapture: a useful methodological tool for counting traffic related injuries? Injury Prevention 6: 299–304.
21. Jamison D, Mosley W, Measham A, Bobadilla J (1993) Disease Control Priorities in Developing Countries Washington, DC: Oxford University Press.
22. Chapman DG (1951) Some properties of the hypergeometric distribution with applications to zoological censuses. Univ Calif Publ Stat 1: 131–160.
23. Brittain S, Böhning D (2009) Estimators in capture-recapture studies with two sources. AStA Adv Stat Anal 93: 23–47.
24. IRTAD (2013) Road Safety Annual Report 2013.
25. Dhillon PK, Lightstone AS, Peek-Asa C, Kraus JF (2001) Assessment of hospital and police ascertainment of automobile versus childhood pedestrian and bicyclist. Collisions 33: 529–537.
26. Kudryavtsev AV, Kleshchinov N, Ermolina M, Lund J, Grjibovskif AM, et al. (2013) Road traffic fatalities in Arkhangelsk, Russia in 2005–2010: Reliability of police and healthcare data. Accident Analysis and Prevention 53: 46–54.
27. Razzak JA, Cone DC, Rehmani R (2001) Emergency medical services and cultural determinants of an emergency in Karachi, Pakistan. Prehosp Emerg Care 5: 312–316.
28. Bhatti JA, Razzak JA, Lagarde E, Salmi L-R (2011) Differences in police, ambulance, and emergency department reporting of traffic injuries on Karachi-Hala road, Pakistan. BMC Research Notes 4: 75.
29. Hook EB, Regal RR (1995) Capture-recapture methods in epidemiology: methods and limitations. Epidemiol Rev 17: 243–264.
30. Emmanuelle A, Jean-Louis M, Bernard L (2007) Estimating non-fatal road casualties in a large French county, using the capture-recapture method. Accident Analysis and Prevention 39: 483–490.
31. Meuleners LB, Lee AH, Cercarelli LR, Legge M (2006) Estimating crashes involving heavy vehicles in Western Australia, 1999–2000: a capture-recapture method. Accident Analysis and Prevention 38: 170–174.
32. Feinberg SE (1972) The multiple recapture census for closed populations and incomplete 2k contingency tables. Biometrika 59: 591–603.
33. Amoros E, Martin JL, Laumon B (2006) Under-reporting of road crash casualties in France. Accident Analysis and Prevention 38: 627–635.