Comparing estimates of road traffic deaths and non-fatal road traffic injuries in Cambodia

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ABSTRACT

Introduction Timely, accurate and detailed information about traffic injuries are essential for managing national road safety programmes. However, there is considerable under-reporting in official statistics of many low and middle-income countries (LMICs) and large discrepancies between estimates from the Global Burden of Disease (GBD) study and WHO's Global Health Estimates (GHE). We compared all sources of epidemiological information on traffic injuries in Cambodia to guide efforts to improve traffic injury statistics.

Methods We estimated the incidence of traffic deaths and injuries and household ownership of motor vehicles in Cambodia from nationally representative surveys and censuses. We compared findings with GDB and GHE estimates.

Results We identified seven sources for estimating traffic deaths and three for non-fatal injuries that are not included as data sources in GBD and GHE models. These sources and models suggest a fairly consistent estimate of approximately 3100 deaths annually, about 50% higher than official statistics, likely because most hospital deaths are not recorded. Surveys strongly suggest that the vehicle fleet is dominated by motorcycles, which is not consistent with GBD estimates that suggest similar numbers of motorcyclist and vehicle occupant deaths. Estimates of non-fatal injuries from health surveys were about 7.5 times official statistics and 1.5 times GBD estimates.

Conclusion Including local epidemiological data sources from LMICs can help reduce uncertainty in estimates from global statistical models and build trust in estimates among local stakeholders. Such analysis should be used as a benchmark to assess and strengthen the completeness of reporting of the national surveillance system.

INTRODUCTION

Reliable estimates of the incidence of road traffic crash injuries and deaths are essential for prioritising road safety on the national agenda, developing safety strategies, allocating resources to effective interventions and appropriate locations, setting targets and monitoring progress.[1 2] The vast majority of global traffic injuries occur in low and middle-income countries (LMICs).[2 3] However, there is considerable uncertainty in the national estimates of traffic deaths and injuries in most LMICs. Estimates based on health sector data sources in many parts of Asia and sub-Saharan Africa are over two times the official statistics.[3 4] In Cambodia, for instance, official statistics are based on traffic police and reported only 1852 deaths in 2016 but WHO's Global Health Estimates (GHE) were 51% higher (2803 deaths, 95% CI 2381 to 3226).[2] Estimates from the Institute for Health Metrics and Evaluation's (IHME) Global Burden of Disease study (GBD, 2870 deaths, 95% CI 2211 to 3527) for the country are substantially higher than official statistics and, in this instance, similar to those estimated by WHO.[5]

Our recent review of population-representative data sources in LMICs found that it is increasingly common for national health surveys and censuses to include questions on the incidence of traffic deaths and non-fatal injuries, the prevalence of disability from such injuries and household ownership of different types of vehicles.[6] These data sources are rarely included in WHO and IHME's statistical models providing an opportunity for external validation of these models. Furthermore, local epidemiological data that have been collected by local agencies are often viewed as more legitimate by national stakeholders. Therefore, comparisons of estimates from additional local data sources with national official statistics can create a more productive debate on the nature of underreporting in the country and how to strengthen statistical systems. Note that the word 'under-reporting' is not intended to suggest deliberate misrepresentation in official statistics but rather weaknesses in the capacity of surveillance systems.[7]

As a case study, we sought to systematically review all sources of epidemiological information on traffic deaths and injuries in Cambodia and compare estimates from various sources. We discuss implications for estimating the true toll of deaths and injuries in this country and elsewhere, and efforts to improve national statistics.

METHODS

We searched for nationally representative data sources from Cambodia, focusing on national household surveys and population censuses that included questions that allow estimating: (1) incidence of traffic deaths, (2) incidence of non-fatal traffic injuries and (3) household ownership of bicycles, motorcycles, cars and other vehicles. We included (3) because per capita vehicles are

important covariates of traffic injuries, and, hence, important for improving estimates in countries where primary data sources on traffic injuries are sparse or unavailable.

We searched PubMed and Google Scholar for articles using: (((*traffic injuries*)) *AND* (*Cambodia*)) *AND* ((*"1990"[Date - Publication]: "3000"[Date - Publication]*)) and conducted further snowball searches based on articles retrieved. In addition, we searched the following data repositories: Integrated Public Use Microdata Series (IPUMS),[8] International Household Survey Network (IHSN),[9] GBD-2019 Data Sources,[10] Global Health Data Exchange (GHDx),[11] Demographic and Health Surveys[12] and International Road Federations World Road Statistics.[13] Finally, we searched government websites for publications that report road safety statistics. In particular, we reviewed statistics reported by Cambodia's national traffic injury surveillance system, Road Crash and Victim Information System (RCVIS).[14]

We acquired microdata of the sources identified wherever possible and extracted estimates of the incidence of traffic injuries and household ownership of bicycles and motor vehicles. Where microdata were not available, published estimates were extracted. We obtained GBD estimates from the GBD Results Hub.[15] Each GBD revision involves a fresh analysis of historic data and results in new time series. Estimates differ between revisions because the historic pool of data grows as new data sources are identified, and due to changes in methods. While GBD-2019 provides the best current estimate, we have included prior revisions because the evolving estimates provide an additional indication of the level of uncertainty in estimates. Only GBD-2017 and GBD-2019 estimates are available online. For earlier revision, we used data that we had previously downloaded. For GBD-2010 and GBD-2015, we only had access to the estimate for the named year.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

RESULTS

Literature search

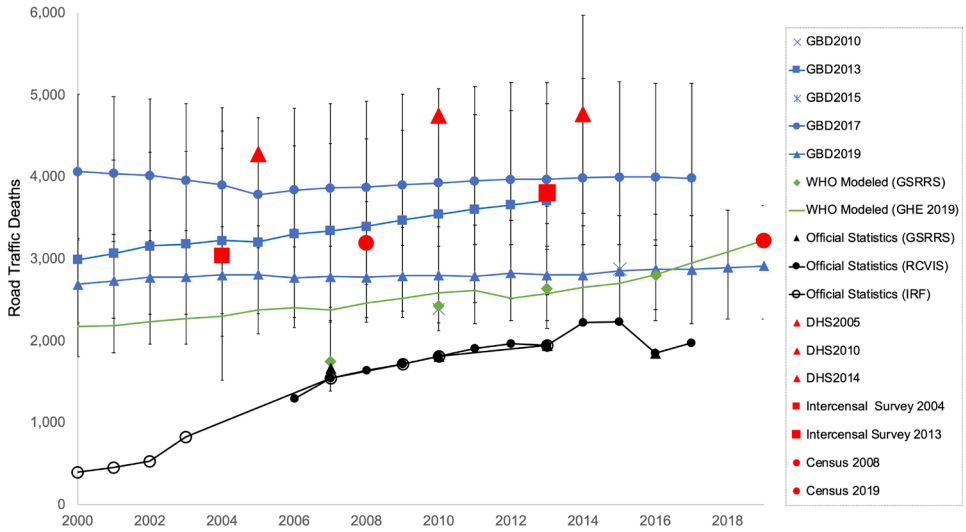
We identified six articles that potentially used nationally representative data sources on the incidence of traffic injuries (online supplemental table A1). However, full-text evaluations revealed only one study,[14] which used a national health survey (Demographic and Health Survey, DHS) to estimate traffic injuries. This paper described and evaluated the RCVIS surveillance system.[14]

Review of censuses and household surveys

We identified eight nationally representative data sources that asked questions potentially relevant for estimating the incidence of traffic injuries in Cambodia (table 1).[16–23] These included: the 2012 Global School-Based Health Survey (GSHS); three DHS surveys (2005, 2010, 2014); two national censuses (2008, 2019) and two intercensal surveys (ICS) in 2004 and 2013. Among these, seven sources (three DHS surveys, two censuses and two ICS surveys) collected information on mortality from traffic crashes. Four sources (DHS surveys and GSHS) collected information on the incidence of non-fatal traffic injuries. However, we excluded the GSHS from analysis because it only collected information about students aged 13–17 years old. The remaining seven sources used identical case definitions (household member injured in 'traffic accident') and recall period (12 months). In addition, we identified 13 data sources with questions on household ownership of vehicles (DHS: 2005, 2010, 2014; Census: 2008; Intercensal survey: 2013, and the

Table 1 Surveys and census with questions pertaining to morbidity and mortality from road traffic crashes

Source name	Source type	Year	Relevant questions
Demographic and Health Survey, 2014[20]	Survey	2014	► Was any person of your household injured or killed in an accident in the past 12 months? ► Could you tell me what type of accident (NAME) was injured or killed? (traffic accident included as option) ► In your opinion, was (NAME)'s injury serious, moderate, or slight? ► Was (NAME)'s death due to the accident?
Global School-Based Health Survey, 2012[23]	Survey	2012	► During the past 12 months, how many times were you seriously injured? ► During the past 12 months, what was the most serious injury that happened to you? ► During the past 12 months, what was the major cause of the most serious injury that happened to you? (Options include 'I was in a motor vehicle accident or hit by a motor vehicle')
Demographic and Health Survey, 2010[19]	Survey	2010	► Was any person of your household injured or killed in an accident in the past 12 months? ► Could you tell me what type of accident (NAME) was injured or killed? (traffic accident included as option) ► In your opinion, was (NAME)'s injury serious, moderate, or slight? ► Was (NAME)'s death due to the accident?
Demographic and Health Survey, 2005[18]	Survey	2005	► Was any person of your household injured or killed in an accident in the past 12 months? ► Could you tell me what type of accident (NAME) was injured or killed? (traffic accident included as option) ► In your opinion, was (NAME)'s injury serious, moderate, or slight? ► Was (NAME)'s death due to the accident?
Intercensal Population Survey, 2013[17]	Survey	2013	► Deaths in household in the last 12 months? ► Total number of deaths? ► What was the cause of death? (road accident included as option)
General Population Census of Cambodia, 2019[22]	Census	2019	► Deaths in household in the last 12 months? ► Total number of deaths? ► What was the cause of death? (road accident included as option)
General Population Census of Cambodia, 2008[21]	Census	2009	► Deaths in household in the last 12 months? ► Total number of deaths? ► What was the cause of death? (road accident included as option)
Intercensal Population Survey, 2004[16]	Survey	2004	► Deaths in household in the last 12 months? ► Total number of deaths? ► What was the cause of death? (road accident included as option)



* Official statistics are based on GSRRS reports, and the Road Crash and Victim Information System (RCVIS) as reported by King and Pen 2020 [28]
** Microdata were not available for Census 2019. Therefore, we applied the tabulated age- sex- specific fractions of all-cause deaths that were due to road traffic injuries to the GBD estimates of all-cause deaths in the country in 2019.

Figure 1 Comparison of various sources of estimates of road traffic deaths in Cambodia. Official statistics of road traffic deaths in Cambodia are shown in black, modelled estimates are in blue (GBD) and green (WHO), and our estimates from analysis of surveys and censuses are shown in red. DHS, Demographic and Health Surveys; GHE, Global Health Estimates; GBD, Global Burden of Disease; GSRRS, Global Status Report on Road Safety; IRF, International Road Federation; RCVIS, Road Crash and Victim Information System .

Cambodia Socio-Economic Surveys (CSES): 2009, 2010, 2012, 2013, 2014, 2015, 2016 and 2017).

Comparisons of estimates of road traffic deaths and injuries

Figure 1 compares official statistics of traffic deaths in Cambodia (shown in black) against GBD estimates (blue), WHO-GHE/GSRRS (green) and our analysis of surveys and censuses (red). Official statistics are substantially lower than all of the estimates except for 2007 when the WHO estimates were nearly identical to official statistics.[7] However, subsequent GSRRS reports predict higher estimates of traffic deaths than official statistics.

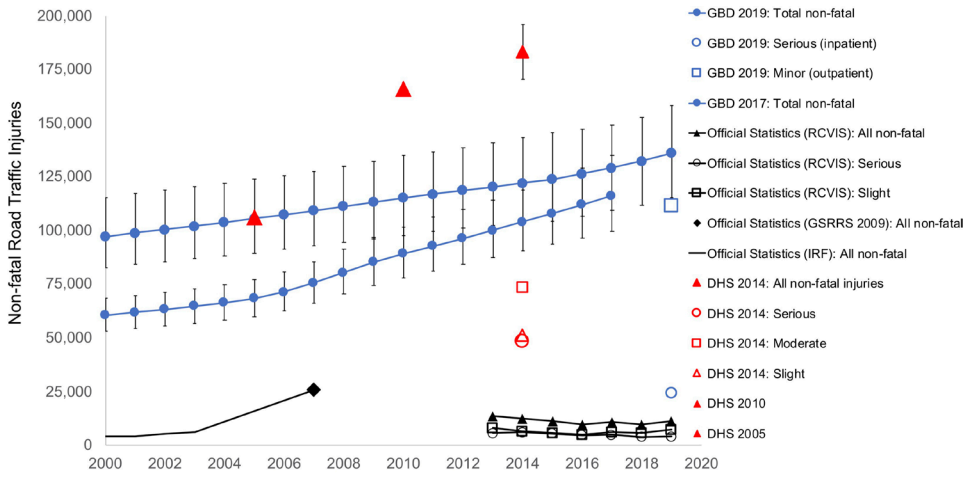
GBD estimates of traffic deaths in Cambodia have changed substantially with each revision. GBD-2013 increased estimates by about 48% compared with GBD-2010; GBD-2015 revised them downwards by 22%; GBD-2017 upwards by about 38%, before GBD-2019 reverted estimates back to approximately GBD-2015 levels. In addition to the large changes with each revision, GBD estimates show large uncertainty. In comparison, WHO's estimates appear to be more stable. Although the modelled estimates reported by GSRRS-2009 have been revised upwards by 42%, all subsequent GSRRS estimates are broadly consistent with the most recent WHO GHEs.

Notably, estimates for the year 2019 from GBD and WHO are similar and consistent with the most recent census estimate of 3220 deaths in 2019. Previous census and intercensal estimates suggest that traffic deaths may have been rising until about 2012 but have been declining since, although this may not be a real trend, and is not reflected in GBD and WHO estimates. Estimates based on the three DHS surveys are consistently higher than GBD, WHO and census estimates. However, these are based on small sample sizes and have large uncertainty intervals that overlap with GBD and WHO estimates.

Figure 2 compares official statistics of non-fatal traffic injuries in Cambodia (shown in black) against GBD estimates (blue) and our analysis of the DHS-2014 survey (red). Official statistics are dramatically lower than estimates reported by GBD and DHS-2014 and show a declining trend. Official statistics report only 6425 serious injuries in 2014, while the DHS estimate is 7.5 times higher (48 500 serious injuries (95% CI 41 190 to 55 808)). The discrepancy is even larger if minor injuries are included. Official statistics in 2014 report 13 780 total injuries, while the DHS-2014 estimate is 13 times higher (183 138 total injuries, (95% CI 170 409 to 195 868)). The GBD estimate of total injuries (122 124 (95 CI 103 728 to 143 245)) in 2014 is 33% lower than the DHS-2014 estimate. GBD's estimates of non-fatal injuries disaggregated by injury severity were only available for 2019. Estimates of injuries requiring inpatient care were 6 times official statistics (24 760 vs 4097), and estimates of total injuries were 12 times official statistics (135 968 (95% CI 115 215 to 158 113) vs 11 368).

Figure 3 shows estimates of household ownership of bicycles and vehicles based on surveys and censuses. Household ownership of bicycles in Cambodia has always been high and relatively stable at about 50%. In contrast, motorcycle ownership by household has steadily increased from 23% in 1990 to 79% in 2017. Car ownership in Cambodia is much lower by comparison, and while it appears to have increased in the last two decades, current levels are only about 6%.

Figure 4 compares the proportions of different road-users killed in crashes in Cambodia based on official statistics (RCVIS) and GBD. RCVIS reports that 73.5% of deaths are motorcyclists, 12 times more than the proportion of vehicle occupants (6.2%), broadly reflecting the household vehicle ownership estimates (figure 3). In contrast, GBD estimates suggest that only one-third of traffic deaths are motorcyclists, approximately the same number as vehicle occupants. The true distribution of road-users killed in Cambodia is not known because we should expect that the under-reporting levels of traffic deaths in official statistics (figure 1) likely varies by road-user type.[24] However, figure 4 strongly suggests that GBD severely underestimates motorcyclist deaths, especially in recent years.



* Official statistics (black) are based on GSRRS-2009, the Road Crash and Victim Information System (RCVIS), and the Minstry of Public Works 2021. [29]

Figure 2 Comparison of various sources of estimates of non-fatal road traffic injuries in Cambodia. DHS, Demographic and Health Surveys; GBD, Global Burden of Disease; IRF, International Road Federation; RCVIS, Road Crash and Victim Information System.

DISCUSSION

Estimates of road traffic injuries in Cambodia

There is remarkable consensus in the estimates of the total traffic death toll in Cambodia. The most recent estimates from WHO (GHE/GSRRS-2018) and IHME (GBD-2019), as well as our analysis of surveys and censuses, suggest that there are approximately 3000 deaths from traffic crashes annually (figure 1). Notably, this estimate is about 50% higher than official statistics, likely due to under-reporting in official statistics. These findings are consistent with a recent review of the crash data system of Cambodia,[25] which concluded that official statistics (RCVIS) do not include most hospital deaths. They noted, '… *police only include road traffic casualties who die before arriving to the hospital*'. While RCVIS includes hospital data in principle, in reality hospitals report less than 2% of total traffic deaths, an impossibly low number.[25] In contrast, 33% of traffic casualties die in the hospital in the Netherlands[25] ; 55% in Iran.[26]

The agreement between GBD and GHE/GSRRS is surprising because neither includes these mortality data sources in their statistical models at present. For countries (like Cambodia) where neither project incorporates local epidemiological data, IHME[27] and WHO[4] estimate traffic deaths based on variables that describe the country's income, motorisation levels, health system characteristics and demographic and transport indicators. However, there are significant differences in modelling details. For example, while WHO's models are calibrated only on countries with high-quality national vital registration data, GBD uses many more sources, including health surveys, verbal autopsies and data representative at the subnational level. Such differences

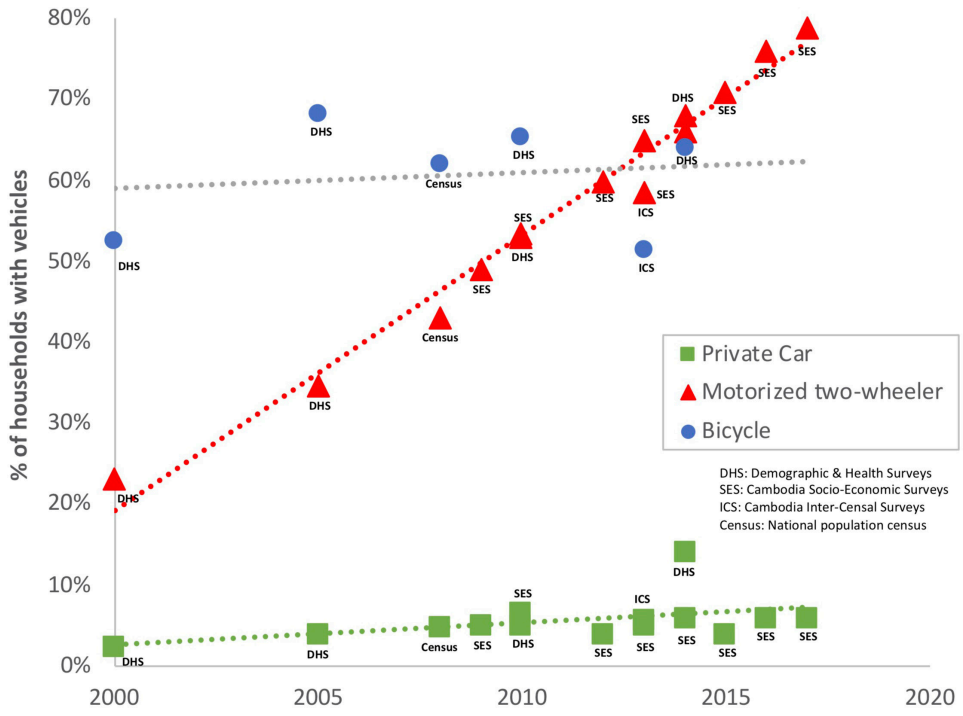


Figure 3 Percentage of households that own a bicycle, motorised two-wheeler or private car.

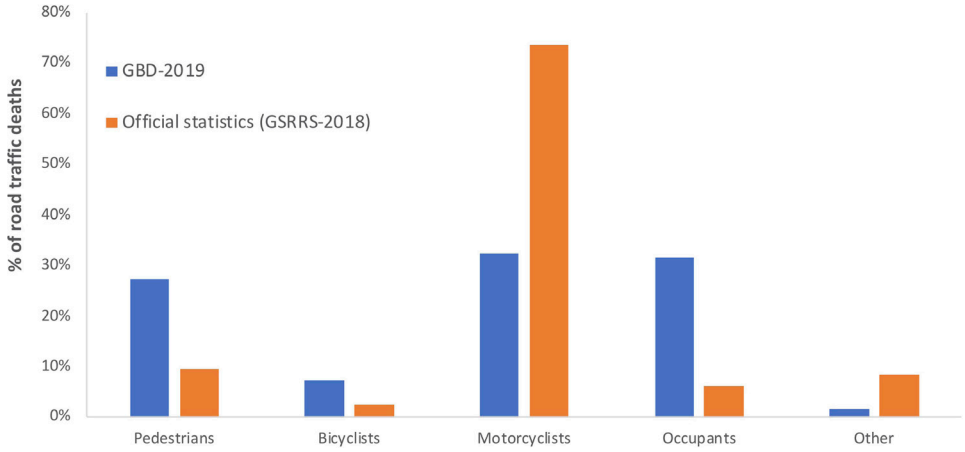


Figure 4 GBD estimates of types of road users killed in 2016 compared with official statistics. GBD, Global Burden of Disease; GSRRS, Global Status Report on Road Safety.

often result in fairly large discrepancies between country-level estimates in many LMICs.[6] In fact, as our results for Cambodia show (figure 1), changes in the modelling strategies between the various revisions of GBD alone result in large changes in estimates.

Unlike the consistency in total deaths, there is a large discrepancy in estimates of the road-user distribution of traffic deaths, which is a serious problem for safety programmes in the country. While WHO does not estimate road-user distribution (GSRRS reports only distributions from official statistics), GBD's estimates of the proportion of motorcyclists killed in crashes are much lower than official statistics and are not consistent with the available evidence about vehicles in the country, especially considering that use of motorcycles has a risk of death that is much higher than four-wheeled vehicles.[28] Surveys show a strong increase in household ownership of motorcycles (doubling every 5 years, figure 3). In contrast, GBD estimates that motorcyclist deaths have been flat for the last 15 years (976 motorcyclist deaths in 2005 and 924 deaths in 2019). GBD likely substantially underestimates motorcyclist deaths (while overestimating deaths of vehicle occupants and other types of road users) because GBDs estimate of per capita motorcycle ownership in Cambodia is incorrect. In 2016, there were almost three times as many motorcycles in the country as estimated by GBD (see Supplementary Appendix for detailed comparison).

Estimates of the incidence of non-fatal injuries also differ substantially across the data sources. DHS estimates for non-fatal injuries are likely reliable because non-fatal injuries are not a rare event (eg, DHS-2010 identified 846 non-fatal injuries). However, it should be noted that injury severity in the DHS is based on the opinion of the respondent. Therefore, based on the DHS, we estimate approximately 50 000 serious traffic injuries (ie, about 16 times the number of deaths) and 180 000 total non-fatal injuries (ie, about 60 times the number of deaths) in Cambodia, annually. These findings are consistent with a recent review of the ratio of deaths to injuries ('injury pyramid'), which concluded that existing evidence from around the world suggests that there are likely 15 serious injuries for every fatality.[24] The DHS estimates of non-fatal injuries appear to be substantially higher than those from GBD. However, the estimates are not directly comparable because GBD uses a different definition of injury severity (ie, cases that would have received inpatient or outpatient care, or would have, if such care were readily available). Official statistics give much lower values for the number of non-fatal traffic injury cases than any of the sources (figure 2), most likely due to severe under-reporting.

It is important to note the limitations of using censuses and surveys for tracking traffic injuries. Self-reported data from household surveys can have biases due to differential item functioning, memory decay and telescoping.[29–32] Importantly, surveys cannot be used as the primary source of information for traffic injury surveillance because they cannot provide the timely and detailed information that is needed to meet the information requirements of running an evidence-based national road safety programme. This requires investments in national surveillance infrastructure, such as the RCVIS,[14] which is managed by the General Secretariat of the National Road Safety Committee (NRSC). Following the international standard, NRSC defines traffic deaths as those that occur within 30 days of the crash.[25] RCVIS includes many variables that are relevant to policy, including the types of road users involved in crashes, sociodemographic characteristics of those involved, use of safety equipment, drink driving status and crash location. Such variables cannot be reliably tracked using surveys, but such detailed information is needed to identify the most important risk factors and to implement targeted interventions and road safety campaigns

Our findings should be used as a benchmark against which completeness of reporting by RCVIS can be assessed. The underlying basis for information on traffic deaths in the RCVIS is primarily police reports, which is usually the only viable source of information for tracking traffic deaths in LMICs. Our analysis shows substantial under-reporting of deaths. Caution is necessary with data on deaths from RCVIS, not only because the values are low but also because the data are likely biased. The deaths may tend to be of certain types of road-users, or from certain provinces.[24] Although our analysis is focused on national estimates, subnational analyses of the censuses and intercensal surveys can estimate under-reporting at the provincial level. The addition to a future survey of a question on the mode of transportation of people killed in traffic crashes would enable assessment of the reliability of RCVIS data on deaths by type of road user. In the shorter term, a follow-back study that collects additional information about a representative sample of the traffic deaths identified in the 2019 census could provide a detailed understanding of under-reporting and statistical bias in RCVIS values and guide efforts to strengthen this national information source.

Under-reporting of non-fatal traffic injuries in RCVIS is much more severe than under-reporting of deaths. DHS-2014 estimates of serious injuries are 7.5 times, and total injuries are 13 times, the statistics on non-fatal injuries are reported by RCVIS. The ratio of severe injuries to deaths (often referred to as the 'injury pyramid') in the RCVIS is approximately 2. Analysis of statistics from other countries suggests that the ratio averages close to 16.[24] Furthermore, the RCVIS reports show a declining trend in non-fatal traffic injuries (figure 2). With such large under-reporting, the risk of bias in the data is very high and it is unlikely that the RCVIS provides a representative description of non-fatal traffic injuries in Cambodia. Nevertheless, an evaluation of RCVIS records for 2010 by the US Centres for Disease Control (CDC) found that RCVIS reports are used extensively by national stakeholders in policy dialogue.[14] Furthermore, the evaluation found that the participation of hospitals in RCVIS was low and inconsistent. Reasons for non-participation included the high administrative burden associated with filling forms, the absence of financial incentives to encourage recording and concerns among health facility workers about patient confidentiality. The CDC evaluation recommended several measures to strengthen reporting of non-fatal injuries, but our analysis suggests that the situation has not improved since 2010. We caution against using RCVIS data on non-fatal injuries until reporting have improved.

Implications for global modelling efforts

Finally, this case study of the various estimates of the incidence of traffic injuries in Cambodia provides some insight into an approach that can be used to improve the global estimates generated by IHME and WHO. Our research shows the value of identifying, assessing and incorporating all sources of local epidemiological data. There is considerable uncertainty in the estimates of traffic injuries in many LMICs. For Cambodia, this uncertainty is evident in the large uncertainty ranges that accompany the WHO and GBD estimates, the differences between the WHO and GBD estimates, and the dramatic shifts in estimates between various revisions of GBD (figure 1). It is likely that the instability in these modelled estimates could be significantly reduced through the inclusion of local epidemiological data. Our review of data sources used by GBD and GSRRS suggests that neither has included the two censuses, two intercensal surveys, nor the DHS, from Cambodia. Such data sources exist in LMICs but have typically not been used in GBD and WHO's models. This case study illustrates that the estimates generated using these data sources are reasonably consistent. Their inclusion in GBD and WHO models can help reduce uncertainty in estimates and the inclusion of local data sources can also build confidence in the estimates among local stakeholders.[1]

What is already known on this subject?

- Running evidence-based road safety programmes requires reliable estimates of the incidence of traffic injuries and key risk factors.
- Official statistics in most low-income and middle-income countries, including Cambodia, are suspected to under-represent deaths and severe injuries.

What this study adds?

- In Cambodia, there are multiple household surveys and population censuses that can be used to estimate national deaths and injuries from traffic crashes.
- Existing epidemiological evidence strongly suggests that deaths in Cambodia are about 50% higher, and non-fatal injuries are more than seven times higher, than official statistic
- Estimates from surveys and censuses should be used to benchmark official statistics in low-income and middle-income countries.
- Including local epidemiological data sources can help reduce uncertainty and discrepancies in estimates of traffic injuries produced by the Global Burden of Disease study and those from the WHO.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study does not involve human participants.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. Survey and census datasets were obtained from the agencies that undertook data collection. Other researchers may obtain the datasets by requesting access from these agencies.

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