Applying the Haddon matrix conceptual model to guide motor vehicle crash injury research and prevention in Botswana

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ABSTRACT

Introduction: Little literature addresses the burden of injury in Botswana, including trauma from motor-vehicle crashes (MVCs). In response, the University of Botswana and the Botswana Ministry of Health and Wellness are collaborating with the University of Pennsylvania to enhance injury and trauma research capacity in Botswana. Here we describe this training program and a research exercise to identify opportunities to prevent, through future research and countermeasures, MVCs specifically in Botswana.

Methods: We initiated a mixed-methods study during a training module during the first two years of the program. The module introduced the Haddon matrix as a conceptual framework, and asked trainees to identify host, vector, and physical/social environment risk factors for MVCs that, if targeted, may lead to primary, secondary, or tertiary prevention. We conducted 10 photovoice elicitation interviews; results were thematically analyzed to further elucidate the context of MVCs in Botswana and potential countermeasures.

Results: Our process identified a range of ideas as barriers or facilitators to MVC prevention. The most commonly cited barriers were animals on the road, drunk or reckless driving, poor road quality, lack of road signs/traffic signals to orient drivers, and poor visibility (e.g., no street lighting; poor lighting on vehicles). Regarding primary prevention, participants identified features prior to the crash, across all matrix levels, as influencers of crashes in Botswana. Among these, several human factors (i.e., over-speeding; drunk driving) and environmental factors (i.e., livestock on road) were commonly mentioned as contributors to MVCs, as were cattle gates and traffic calming measures for prevention.

Conclusion: Results of the Haddon matrix exercise proved useful for training burgeoning Batswana researchers to think conceptually about the occurrence of MVCs in Botswana and think creatively about targeting countermeasures for prevention. The exercise resulted in potential research questions for the trainees to pursue in mentored research of their own.

African relevance

- Preventing motor vehicle crashes and their harm to individuals, healthcare, and the economy is a priority for Botswana.
- This study was conducted within an injury research training program with Batswana trainees.
- As part of their careers, these trainees are in a position to design and evaluate countermeasures to prevent motor vehicle crashes.
- The training program, exemplified by the completed exercise, is building Botswana’s capacity to conduct research for injury prevention.
Introduction

Injury – from violence, self-harm, and unintentional events – is a major global public health problem. According to the World Health Organization, injuries represent 36% of global disability-adjusted life-years and 16% of the global burden of disease [1]. Motor vehicle crashes (MVCs) are a major cause of injury-related deaths and comprise 24% of the world’s injury fatalities [1], killing approximately 1.24 million people each year [2]. Non-fatal injuries impact an additional 50 million people annually, making MVCs the world’s leading cause of life-long disability [3].

The number of MVCs occurring in Africa doubled between 1990 and 2015 [4], where the percent of deaths attributable to MVCs outpaces that in the rest of the world. In 2016, MVCs accounted for 3.2% of all deaths in Africa, but only 0.5% of deaths globally [5]. As the proportion of deaths from MVCs continues to rise, so will the disparity in the percentage of African deaths caused by MVCs. By 2030, MVCs are expected to cause 4.4% of the continent’s deaths, compared to 2.7% deaths in the rest of the world [5].

In Botswana, injury has been referred to as the nation’s second epidemic, yet there is little literature on the burden of MVC-related trauma and prevention needs in the country. One study found that trauma was the second most common condition presenting to the largest referral hospital in Botswana for every age group, and that MVCs in their experience were the predominant cause of the trauma [6]. MVCs are a particularly important public health concern for policy makers in Botswana as the 17,786 MVCs in 2017 cost the country an estimated US $174.7 million [7]. Additionally, MVCs are a leading cause of death and disability burden for the country, and Botswana’s MVC death rate of 24 per 100,000 is higher than the global average of 17.4 deaths per 100,000 [8].

To address this public health problem, the University of Botswana (UB) and the Ministry of Health and Wellness (MoHW) collaborate with the Fogarty International Center of the National Institutes of Health (D43TW010448) in the United States, an injury and trauma research training program designed to produce independently functioning Botswana injury scientists and research teams. By leveraging existing partnerships among these institutions and implementing a comprehensive training program, it aims to: 1) increase trainee expertise in the disciplines of epidemiology and public health research, health services research, and biostatistics; 2) foster applications of the methods and skills of public health and epidemiologic research to address priority issues regarding etiology, early detection, treatment, prognosis, prevention, and recovery following trauma and injury; and 3) integrate faculty and trainees at Penn, UB, and the MOH. Ultimately, this training program will develop a cadre of independent, extramurally-funded Botswana researchers and supporting infrastructure at UB and the MOH for trauma and injury research and prevention.

Program structure and enrollment

The training program has two pathways: Independent Investigator (II) and Associate Investigator (AI). For II training, Botswana trainees enroll either in the Penn program for a Master of Science in Clinical Epidemiology (MSCE) or Master of Science in Health Policy Research (MSHP), which are two-year programs with the first year spent on coursework at Penn and the second year on a research project in Botswana. The program enrolls one or two trainees annually with a target of six trainees at the end of the five-year program. These trainees form the core of an extended research group in Botswana. The AI training pathway provides bi-annual one- to five-day didactic training modules in Botswana. The trainees are research coordinators, health administrators, clinicians, nurses, and criminal justice professionals who comprised an initial cadre of seven trainees, with enrollment expanding as the program progresses. The modules impart research skills training to enhance the injury epidemiology workforce in Botswana, and lead to collaborations that empower both AI and IIs in future research projects.

This paper describes the process and results of one of the training modules conducted with AIs during the first two years of the program. The module introduced the Haddon Matrix as a conceptual framework so that AIs could brainstorm Botswana-specific MVC intervention strategies. The group completed photovoice elicitation interviews to further elucidate the context surrounding the causes of MVCs in Botswana.
Table 1  
Haddon’s Matrix populated with ideas for risks of and countermeasures for motor vehicle crash-related injuries in Botswana.

| Human factors                                                                 | Vehicle factors                                                                 | Environment factors                                                                 | Social factors                                                                                                                                 |
|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| **Pre-Crash**                                                                 |                                                                                |                                                                                    |                                                                                                                                             |
| • Cultural attitudes of farmers allow animals to open graze                    | • People add reflective tape on cars to increase their visibility (protective)  | • Bott’s dots increase visibility of roads at night (protective)                    | • Lack of government upkeep of road conditions perpetuates poor road conditions; non-working traffic lights; many potholes (2 participants)  |
| • Education about safe road crossings and use of crosswalks (protective, 2 participants) | • No handbrakes or signal lights for combis                                    | • No road markings, traffic signals, or signs to guide drivers about road features (curves, oncoming traffic, etc.) (2 participants) | • Unsuccessful government attempts to maintain dilapidated fences to keep farm animals contained (2 participants)  |
| • Pedestrians not wearing visible and reflective clothing at night             | • No governors to moderate speed for combis or other fleet vehicles            | • No lights on the highways limits visibility of animals on roads at night            | • Same pay day for all at the end of the month promotes intoxication and drunk driving (2 participants)  |
| • Over-speeding on highways is common, especially by combis                    | • Cars have poor lighting, cannot see animals on roads (2 participants)         | • Fluorescent reflector neck bands on livestock to increase visibility of domestic animals at night (protective) | • Mandated stickers to signal maximum speed for combis are used, but are not effective  |
|                                                                                |                                                                                | • No barricades for pedestrians to prevent them from crossing at unsafe intersections | • No laws to ticket jaywalking  |
|                                                                                |                                                                                | • Cross-guards/police in the morning to help children cross safely (protective)    | • Lack of laws concerning safety equipment of vehicles  |
|                                                                                |                                                                                | • Road bumps to force people to slow down for children in morning (protective)      |                                                                                                                                             |
|                                                                                |                                                                                | • Animals in the road that are particularly difficult to see at night (3 participants) |                                                                                                                                             |
|                                                                                |                                                                                | • Light signals that do not work (3 participants)                                   |                                                                                                                                             |
|                                                                                |                                                                                | • No zebra crossings for pedestrians at night                                      |                                                                                                                                             |
| **At Crash**                                                                  |                                                                                |                                                                                    |                                                                                                                                             |
| • Injuries are more severe if thrown from donkey cart                         | • Lack of seatbelts (2 participants)                                            |                                                                                    |                                                                                                                                             |
| • Injuries are more severe if there are more objects like poles, stones, or decorative statues in traffic circles (roundabouts) | • Lack of infant/child car seats in vehicles (2 participants)                  |                                                                                    |                                                                                                                                             |
| **Post-Crash**                                                                |                                                                                |                                                                                    |                                                                                                                                             |
| • First aid training to engage bystanders (protective)                        | • Ambulance vehicles are ill equipped for emergency medical service (EMS) personnel to assist patients in transit from crash site to nearest appropriate hospital | • Crashes occurring in remote locations are far from hospitals with trauma care    | • Emergency medical service (EMS) personnel are not properly trained and Botswana needs more of this type of medical provider  |
|                                                                                |                                                                                |                                                                                    | • Emergency medical services (EMS) sends crash victims to nearest facility, which may not be equipped for trauma care |
livestock may prove fruitful for designing effective MVC countermeasures in Botswana.

Structural factors

The structural factors participants identified as potential motor vehicle crashes influencers included unsafe forms of commercial public vehicles, such as combis. Combis (or kombis) are privately owned minibuses that operate between towns and are a popular form of public transportation in Botswana. Participants cited combis' excessive speeding as a factor influencing road motor crashes. They suggested that the government should enforce the mandated combi speed limits shown on the stickers because, despite the stickers, combi drivers do not adhere to speeding limitations. Participants suggested introducing speed governors on combis and on other types of vehicle fleets as a potentially effective crash prevention countermeasure. Indeed, many vehicle fleets post a sticker on their vehicles indicating the maximum speed that the driver is expected to not exceed (Fig. 3), suggesting that companies recognize the value of speed control. Relying on driver behavior, however, is an “active intervention” in that to be effective, an individual change their behavior, and thus is a relatively weak countermeasure [15]. A stronger countermeasure could be achieved by installing a governor on those vehicles that make excess speed impossible (a “passive intervention”).

Policy factors

Most participants discussed drunk driving during their interview, although it was not documented with a photograph. Participants raised concern that the timing of paydays in Botswana could encourage drunk driving because most paydays occur around the same time of the month resulting in large numbers of workers that drink excessively within a short period of time, thereby increasing the risk of crashes. This finding is supported by reports in Guatemala which showed that drunk driving-related crashes spiked on days when paydays coincided with a holiday [16]. The participants suggested that further research is needed about drunk driving prevention and the specific risks that emerge during mini-weekends around pay days. Regarding speed governors,
participants identified a barrier in that leadership of certain corporations with maximum speed stickers on their vehicles previously opined that higher speeds are not appreciably dangerous, or that their company's priority is facilitating unhampered vehicle travel to maximize revenue.

Participants’ research recommendations

An output from the interviews was that the AIs proposed a variety of potential research questions to help explore and explain the problem of MVCs in Botswana. Next, further comprehensive in-country research should be conducted to investigate the factors contributing to road crashes, including the relationship between road quality, road visibility at night, traffic lights, pedestrians, protective barricades, and crashes using different research approaches including geospatial analysis, randomized control trials to determine the effectiveness of combi speed governors, qualitative analysis to identify and design potential interventions that are culturally acceptable, case studies of existing programs (such as an examination of the solar light pilot data), and policy analysis.

Discussion

The photovoice interviews, using the Haddon matrix conceptual framework and thematic analysis, yielded valuable results from the AIs about factors influencing MVCs in Botswana. One MVC feature salient to most participants was livestock on the road. Since participants described this problem as rooted in farmers’ preferences, further qualitative examination could elicit why farmers prefer open-grazing; the findings could inform culturally amenable countermeasures to prevent MVCs. Except for the role of livestock, the Haddon matrix results align with the World Health Organization’s (WHO) prior research about global road traffic risk factors [17,18]. The WHO report expands upon the Haddon matrix to establish systems-level (where interactions between different components are taken into account) and research-driven approaches to address road traffic injuries as a public health problem. Incorporating local government buy-in may be necessary for successful reduction in MVCs in Botswana. Participants suggested that government agencies have greater authority to regulate public transportation, such as combis, and improve road planning (signs, markings, and visibility). Working to enhance the relationships between researchers and policymakers could also help create robust, systematic data-reporting systems within the county to accurately measure the scope of the MVC problem, an essential component for designing prevention interventions [4,6,19]. Additionally, successful implementation of interventions may need to include a “third dimension” for decision making, such as cost and feasibility, which requires more accurate data reporting [10].

Conclusions

The Haddon matrix exercise proved useful to training burgeoning Batswana researchers to think conceptually about the occurrence of MVCs in Botswana and strategize creatively about targeted opportunities for prevention. The exercise resulted in potential research questions for the trainees in the II pathway to pursue in research of their own. In order to facilitate data access and more accurate reporting of MVCs, cooperation with government officials and departments like the Motor Vehicle Accident Fund and the Botswana Police Service should be strengthened. A potential benefit of increased collaboration among researchers and government officials would be the development of more robust data-reporting systems in Botswana, which could facilitate the design of interventions to prevent MVCs.

Dissemination of results

Results of this study will be shared throughout the Botswana-UPenn Partnership (https://www.med.upenn.edu/bo/orvana/), which works with the Botswana Ministry of Health and Wellness and the University of Botswana, and whose members include research coordinators, students, faculty, nurses, physicians, researchers, public health officers, and policy makers.

Author contributions

Authors contributed as follows to the conception or design of the work; the acquisition, analysis, or interpretation of the data for the work; and drafting the manuscript or revising it critically for important intellectual content: CB contributed 40%; DJW 20%, YM 10%; and PM, OF, LMN, OM, EM, BK, TM, JHH, VT, and FKB 3%. All authors approved the version to be published.

Declaration of competing interest

The authors declare no conflicts of interests that require disclosure.

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