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Economic development and road traffic fatalities in two neighbouring African nations

Développement économique et décès occasionnés par les accidents de la route dans deux pays africains voisins

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Introduction: The rapid growth of Botswana's economy since independence in 1966 has brought more tarred roads and vehicles, accompanied by an escalating road crash fatality rate. We tested the hypothesis that motor vehicle crash fatality increases resulted from, rather than just corresponded with, annual gross domestic product (GDP) increases. Data from Zambia, adjacent to Botswana, were used for comparison.
Methods: Annual social and economic indicators and motor vehicle crash fatality rates in Botswana and Zambia were accessed from 1960 to 2012 and analysed using vector autoregressive analysis and Granger causality tests.
Results: In Botswana, annual changes in per capita GDP predicted annual changes in motor vehicle crash fatality rates ($p = 0.042$). The opposite was not observed; annual changes in motor vehicle crash fatality rates did not predict annual GDP changes. These findings suggest that GDP growth in a given year caused additional road traffic fatalities in Botswana and that, on average, every billion dollar increase in GDP produced an increase in the rate of road traffic fatalities. In Zambia, annual GDP changes predicted annual fatality rate changes three years later ($p = 0.029$), but annual changes in road crash fatality rates also predicted annual increases in per capita GDP ($p = 0.026$) three years later, suggesting a correlation between trends, but not a causal effect of GDP.
Conclusion: Road crash fatalities increased in recent decades in both Zambia and Botswana. But the rapid economic development in Botswana over this time period appears to have driven proportionate road traffic fatality increases. There are opportunities for newly emerging economies such as Zambia, Angola, and others to learn from the Botswana experience. Evidence-based investments in road safety interventions should be concomitant with economic development.

Introduction: La croissance rapide de l'économie du Botswana depuis l'indépendance en 1966 s'est traduite par le développement du nombre de routes goudronnées et de véhicules, accompagnés d'un taux de mortalité due aux accidents de la route qui va s'accélérant. Nous avons testé l'hypothèse selon laquelle les hausses de la mortalité due aux accidents de véhicules motorisés seraient attribuables aux augmentations du produit intérieur brut (PIB), plutôt que d'en être un simple reflet. Des données provenant de Zambie, pays adjacent au Botswana, ont été utilisées pour établir une comparaison.
Méthodes: Des indicateurs économiques et sociaux annuels et les taux de mortalité due aux accidents de la route au Botswana et en Zambie ont été examinés sur la période 1960–2012 et analysés en utilisant une analyse vectorielle autorégressive et des tests de causalité au sens de Granger.
Résultats: Au Botswana, les variations annuelles de PIB par habitant ont prédit les variations annuelles des taux de mortalité due aux accidents de véhicule motorisés ($p = 0{,}042$). L'inverse n'a pas été observé; les variations annuelles de taux de mortalité due aux accidents de véhicules motorisés ne permettent pas de prédire les variations annuelles de PIB. Ces résultats suggèrent que la croissance du PIB pour une année donnée a causé des décès occasionnés par des accidents de la route au Botswana et qu'en moyenne, chaque augmentation d'un milliard de dollars du PIB a produit une augmentation du taux de décès occasionnés par des accidents de la route. En Zambie, les variations annuelles de PIB ont prédit les variations annuelles du taux de mortalité trois ans plus tard ($p = 0{,}029$), mais les variations annuelles des taux de mortalité des accidents de la route ont également prédit les augmentations annuelles de PIB par habitant ($p = 0{,}026$) trois ans plus tard, ce qui suggère une corrélation entre les tendances mais pas un effet de causalité du PIB.
Conclusion: Les décès occasionnés par les accidents de la route ont augmenté au cours des dernières décennies en Zambie comme au Botswana. Mais le développement économique rapide au Botswana au cours de cette période semble avoir entraîné des augmentations proportionnelles des décès dus aux accidents de la route. Il est possible, pour les nouvelles économies émergentes comme la Zambie, l'Angola, et d'autres, de tirer des leçons de l'expérience du Botswana. Des investissements dans des interventions en matière de sécurité routière, fondés sur des données concrètes, doivent être concomitants au développement économique.

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African relevance

- Road traffic crash is a major cause of morbidity and mortality in Africa.
- There may be a relationship between rapid economic growth in African countries and frequency of road traffic crashes.
- Road safety interventions, especially in African countries with rapidly growing economies, are likely to be beneficial.

Introduction

Low- and middle-income (LMIC) countries carry a disproportionate burden of the death and disability caused by road traffic crashes (RTCs).[1–3] RTCs kill 1.2 million people worldwide each year and are expected to increase by 65% over the next 20 years if left unabated.[1] The World Health Organisation (WHO) predicts that by 2030, RTC injury will become the fifth leading cause of death worldwide, up from ninth in 2004.[4] It is important to determine whether RTC fatalities are an unfortunate unintended consequence, inevitable in a country with a rapidly developing economy. If RTC fatalities are directly due to aspects of economic development, then traffic safety programmes can prioritise modifying risk factors and expanding programmes in developing nations alongside their economies and roadway systems.

The relationship between economic development and traffic fatalities is complex. Studies in 41 out of 88 countries comparing RTC fatality trends with measures of economic development found positive associations.[5–9] In absolute terms, middle-income countries had the highest fatality rates, but when adjusted for the number of motor vehicles, the poorest countries showed the highest road traffic fatality rates.[6] Kopits et al. found that once countries experienced higher gross domestic product (GDP) levels, fatalities per capita declined.[7] However, during the early stages of these countries' economic growths, sharp increases in fatalities per capita were evident as GDP increased. Such a relationship was reported by Winston et al. who found that the sudden economic change resulting from the reunification of Germany led to a dramatic increase in fatalities for car occupants in East Germany.[10]

The WHO and other organisations have emphasised the important contribution of economic development to mobility, increased motorisation and vehicle ownership, increased vehicle miles driven, and therefore increased exposure to risk.[1,7,10,11] In many lower and middle income countries, new high-speed roadways were built to accommodate expanding commerce. Rapid urbanisation and increased travel between urban and rural areas, especially at holiday times, have contributed to increased traffic without proportionately resourced traffic safety systems.[1,7,10,11] Countries with higher economic development, in contrast, tend to have new and existing roadways equipped with traffic safety systems, better public transport, more efficient regulation, higher accountability to public authorities for enforcement, and public education campaigns on road safety; this ultimately has the potential to confer a protective benefit.[7]

There has been a need to intensify research efforts about RTCs in Africa, in particular, improving data quality, increasing surveillance, and implementing actions based on evidence from African countries.[12] New road traffic safety measures are needed in most of sub-Saharan Africa, including Botswana[13] and Zambia.[14] This study tested the hypothesis that annual GDP increases directly cause increases in RTC rates. To test this, this study examined these trends in Botswana and compared them with those in Zambia, a neighbouring country. Both countries gained independence from Britain at similar times: 1966 and 1964, respectively. The World Bank has described Botswana as one of the fastest growing economies in the world until recently,[15] and Zambia, with rapid economic growth for the last decade.[16] By 2007, Zambia had 222,188 registered vehicles. That year, of Zambia's population of 11.9 million people, 10,524 were injured or killed in road traffic crashes.[4] Botswana, with a considerably smaller population of 1.8 million, had 293,755 registered vehicles and 7639 people injured or killed road traffic crashes.[4]

Methods

This study accessed data from the World Bank, WHO, and Botswana Motor Vehicle Accident Fund for socio-economic indicators and annual RTC fatality rates in Botswana and Zambia for the period 1960–2012.[17,18] Data on socio-economic indicators were available for this time period, however data on RTC deaths in Botswana were available only for 1981–2012. This study used the 31-year period for hypothesis testing in Botswana. Similarly for Zambia, this study used data from the period 1981 to 2007 (the most recent year available) for analyses. Data on vehicles per 1000 population were available for most years between 1990 and 2012 for Botswana but for only a few years for Zambia.

The annual data on GDP and RTC deaths were plotted, with changes over time measured as percent changes and average percent changes per year.[4,17] To test the presence of a causal relationship between GDP and RTC deaths, this study then analysed the annual time series of RTC death rates and GDP per capita with vector autoregressive analysis and Granger causality tests. The notion of Granger causality follows: if lagged values of X help predict current values of Y in a time series (i.e., Y regressed against values of X that occurred one year earlier, two years earlier, and so on), and lagged values of Y do not help predict current values of X, then X is said to "Granger-cause" Y.[19] The analysis then tested the relationship between the two time series using up to three annual lags. Consistent with conventional time series methodology, each time series was detrended (i.e., differenced, where from the value of a given year had the value of the previous year subtracted) prior to analysis and evaluated for stationarity using the Dickey–Fuller test. Residuals of the regression analyses were evaluated using normality test, plots of the autocorrelation function, and the Q statistic.

The study was approved by the University of Pennsylvania Institutional Review Board.

Results

The populations of Botswana and Zambia were 531,555 and 3,044,262 respectively in 1960, and 1.90 million and 12.6 million respectively in 2008. Population growth over that time was linear in Botswana but exponential in Zambia. In 2008, GDP in Botswana increased to $8.46 billion and in Zambia,

$4.89 billion (measured in 2010 US dollars). This calculated to an average growth of 132.6% per year in Botswana and 4.1% per year in Zambia. GDP growth outpaced population growth in Botswana whereas population growth outpaced GDP growth in Zambia; this suggests that per capita, GDP levels increased over time in Botswana, but decreased over time in Zambia. In Botswana, the per capita GDP increased from $246 in 1960 to $4,440 in 2008, an average annual change of 35.5%. In contrast, in Zambia the per capita GDP decreased from $545 in 1960 to $387 in 2008, representing an average annual net decrease of 0.6%.

The absolute number of RTC deaths increased in both Botswana and Zambia with 450 deaths in Botswana in 2005 and 890 deaths in Zambia in 2007. However, per capita RTC deaths increased 172.2% in Botswana and decreased 17.1% in Zambia over the observed period of approximately 20 years (Table 1).

In Botswana, vehicles per 1000 population increased from 18 in 1990 to 156 in 2007, an increase of 766.7%, while RTC fatalities per 10,000 vehicles decreased from 128 to 22, a reduction of 82.8% (Table 1). In Zambia, vehicles per 1000 population increased from 14 in 1990 to 19 in 2007, a net increase of 35.7%, while road traffic fatalities per 10,000 vehicles decreased from 76 to 40, a reduction of 47.4%. This suggests that in Botswana, vehicle prevalence grew more quickly than fatalities per vehicle fell. This is consistent with patterns found in other developing countries,[7] however different from the findings observed in Zambia up to 2007.

Conventional diagnostics identified autocorrelation in the time series representing GDP per capita and RTC fatality rates in Botswana (Fig. 1) and Zambia (Fig. 2). Values occurring in adjacent years and closer in time were more similar than values occurring in the more distant future or past. Each time series was therefore differenced before analysis, by subtracting from each value the value that preceded it. As such, each value was equal to the change in the time series from the previous year.

The regression analyses conducted on the time series for RTC fatalities per capita and GDP per capita in Botswana indicated that annual changes in per capita GDP in a given year (compared to the preceding year) were positively associated with annual changes RTC fatalities per capita ($p = 0.042$) in the same year (compared to the preceding year). Granger tests indicated that directionality went from GDP to fatalities and not vice versa, suggesting that GDP "Granger-caused" road traffic fatalities in Botswana (Table 2). On average, every billion-dollar increase in GDP was associated with a proportionate increase in the rate of RTC fatalities.

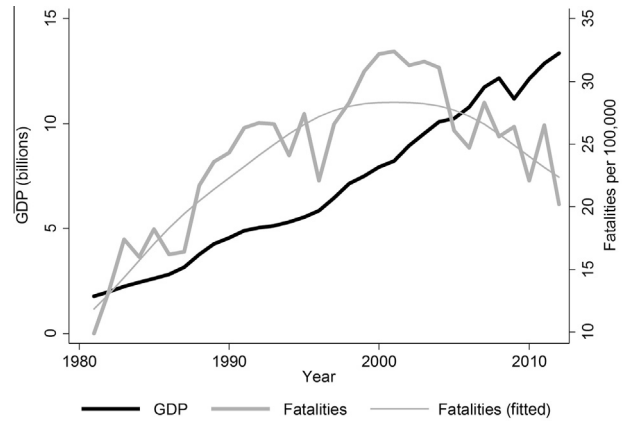

Figure 1 Gross domestic product (US dollars) and road crash fatality rate per 100,000 population in Botswana, 1981–2012.

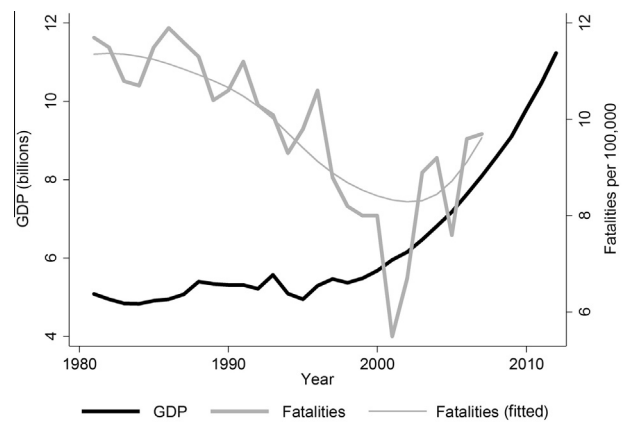

Figure 2 Gross domestic product (US dollars) and road crash fatality rate per 100,000 population in Zambia, 1981–2012.

In Zambia, annual changes in road traffic crash fatality rates predicted annual increases in per capita GDP ($b = 15.64$, $p = 0.026$) three years later, however annual GDP changes also predicted annual fatality rate changes three years later ($p = 0.029$) (Table 3). This does not suggest a causal effect of GDP, but instead is evidence that the two trends are correlated. Although the declining time series of road traffic fatality rates in Zambia stands in contrast to the increasing rate that was observed in Botswana (Fig. 1), it is important to

Table 1 Characteristics of Botswana and Zambia and changes over recent decades. *Source:* The World Bank (2010); World Health Organisation (2009); MVC, motor vehicle crash; GDP, gross domestic product.

	Botswana			Zambia		
	Past**	Present***	Change (%)	Past**	Present****	Change (%)
Population, millions	1.03	2.00	94.2	6.04	12.10	100.0
GDP per capita$,*	1278	4440	247.4	486	387	−20.4
MVC fatalities	93	450	383.9	700	890	27.1
MVC fatalities per 100,000 population	9	24.5	172.2	11.7	9.7	−17.1
Vehicles per 1000 population	18	156	766.7	14	19	35.7
MVC fatalities per 10,000 vehicles	128	22	−82.8	76	40	−47.4

*In US dollars (2000); **1990 for vehicles and 1981 for other characteristics; ***2012; ****2007.

Table 2 Regression tests of the relation between annual change in gross domestic product and annual change in road traffic crash fatalities in Botswana, 1981–2012.

Lags*	Coef.	SE	*p*	95% CI
H_o: lagged GDP changes do not predict road traffic crash fatality changes				
0	4.66	2.18	0.042	(0.18, 9.13)
1	3.32	2.59	0.198	(−1.89, 8.73)
2	−3.88	1.95	0.056	(−7.87, −0.11)
3	1.53	3.94	0.701	(−6.54, 9.59)
H_o: lagged road traffic crash fatality changes do not predict GDP changes				
0	0.013	0.01	0.142	(−0.01, 0.03)
1	0.02	0.02	0.320	(−0.02, 0.05)
2	−0.02	0.01	0.106	(−0.05, −0.01)
3	0.01	0.02	0.474	(−0.02, 0.05)

H_o, null hypothesis; Coef, Coefficient; SE, standard error; *p*, probability value; CI, confidence interval.
* Number of years by which GDP was lagged before road traffic crash fatality rates were regressed upon it, and vice versa.

Table 3 Regression tests of the relation between annual change in gross domestic product and annual change in road traffic crash fatalities in Zambia, 1981–2012.

Lags*	Coef.	SE	*p*	95% CI
H_o: lagged GDP changes do not predict road traffic crash fatality changes				
0	8.47	6.92	0.233	(−5.82, 22.76)
1	−6.22	6.63	0.357	(−19.89, 7.46)
2	2.53	8.29	0.763	(−14.59, 19.65)
3	15.64	6.59	0.026	(2.05, 29.24)
H_o: lagged road traffic crash fatality changes do not predict GDP changes				
0	0.004	0.094	0.293	(−0.004, 0.013)
1	−0.004	0.004	0.306	(−0.01, 0.004)
2	0.001	0.004	0.864	(−0.01, 0.01)
3	0.01	0.004	0.029	(0.001, 0.02)

H_o, null hypothesis; Coef, Coefficient; SE, standard error; *p*, probability value; CI, confidence interval.
* Number of years by which GDP was lagged before road traffic crash fatality rates were regressed upon it, and vice versa.

note that the low point in Zambia occurred in 2001 when the rate was 5.5 per 100,000 (Fig. 2). The rate rose to 9.7 per 100,000 over the six years that followed, calculated as an increase of 76.4%.

Discussion

The WHO observed that to improve global road traffic safety, there must be sound justification to overcome the prevailing perception that RTC fatalities are the "price to be paid" for achieving mobility and economic development.[20] Our results suggest that the RTC fatality rate in Botswana has been directly driven by the economy, rather than growing coincidentally alongside economic growth. Moreover, RTC fatalities in Botswana, mostly accounting for passengers of cars and light trucks (44%), drivers of cars and light trucks (24%), and pedestrians (27%), are preventable.[13,21] From a public health viewpoint, the economic development that causes RTC fatalities are modifiable risk factors.[22] Mupimpila found Botswana lacks the capacity for implementation of road safety improvement, despite a well-equipped government infrastructure.[13] For example, over the course of a recent five-year plan to implement changes, the government built and equipped only two of five planned vehicle testing stations and completed only four of nine planned driving training and testing facilities. A 2012 study on trauma care capacity in Botswana, a critical sector of the healthcare system for RTCs, found that hospitals have been developing physical resources and clinical expertise for trauma care, but trauma team organization, training activities, and plans for trauma care were absent.[23] This indicates that essential trauma care guidelines need to be applied to improve trauma care capabilities essential for care of those in RTCs.[23]

When diamonds were discovered in 1967 in Botswana, there were fewer than five kilometres of tarred roads and only three secondary schools in the country. By 2001 there were 6000 km of roads and 300 secondary schools – and no one in Botswana was more than 30 km from the nearest health facility.[24] Communities in Botswana have clearly benefited from the transportation infrastructure that resulted from economic development. However, these benefits accompany the harm resulting from RTC fatalities. Harm in this study has been quantified as mortality due to the reliability of this type of data. Additional metrics of harm that are harder to measure accurately include disability caused by RTCs, their resulting burden on health services, families, and communities, and

the drain on health service resources, exacerbated by unreliable blood supplies and a lack of specialist emergency medicine skills in district hospitals.[22,25]

Botswana now has the opportunity to make a significant difference to its RTC mortality profile through investment in new initiatives that include the Botswana Society for Emergency Care, a Resuscitation Training Centre, a Trauma Research Centre at the University of Botswana, and the formation of a committee to design a national policy for pre-hospital care.[26] Specialists trained through a recently established postgraduate programme in Emergency Medicine will soon be attending at hospitals at particular hotspots for RTCs.[26,27] The impact of these new advances should be carefully evaluated especially through improved data collection and surveillance systems.

There are many lessons Zambia could consider from the experience of Botswana, in addition to adapting with fewer resources. A 2008 study found that only 50% of hospitals in Zambia had an emergency medical system (EMS) that transported patients.[28] Notably, EMS care was primarily based on rapid transport rather than on treatment at the scene. In addition, only 24% of ambulances carried oxygen and only 40% carried drugs of any kind. The majority of critically ill patients received care in general hospital wards since only 5 of 68 hospitals (7%) reported having an intensive care unit, totalling to 29 beds to serve the entire country. Overall, Zambia had 6.4 doctors per 100,000 population in 2009, whereas Botswana had 39.9.[29]

Even in resource constrained settings there are many actions that can prevent road traffic crashes and subsequent morbidity and mortality. These include preventing speeding, stricter penalties for alcohol drinking and driving, reducing traffic congestion, roadway development to accommodate traffic volume, promotion of public transportation, driver licensing and training, mandatory vehicle performance checks, promoting seatbelt use, separation of vehicles and pedestrians, and fencing to keep animals off roadways.[22,30–32] Current challenges include the increase in transport trucks moving trade through Botswana, the need for overtaking points on single lane highways, and individuals drinking alcohol while driving long distances between their city home, rural home and cattle posts.[13] In order to orchestrate a coordinated approach, Mupimpila recommends establishing a Botswana Road Safety Council and setting quantitative targets for improving road safety.[13]

Those in Zambia should also promote road safety, even with an economic profile different from Botswana.[14] Zambia's RTC fatalities are also different: 37% are passengers of cars and light truck, 37% pedestrians, and 12% drivers of cars and light trucks.[21] This means that Zambia has its own priorities for prevention. Zambia has seen an increase in total RTC deaths of 85% from 2012 to 2014 alongside increasing economic growth.[33] More RTC deaths occur annually in Zambia than in Botswana in absolute terms.[34] An increase in cheaper second-hand vehicles imported from Singapore, Japan and China, that often lack basic safety features like seat belts, removed to reduce shipping costs, are likely one responsible factor.[14] There is a need to urgently enforce traffic safety policies in Zambia to achieve maximum benefit from prevention strategies. As a result, the Zambian Road Safety Trust, a non-profit advocacy organisation, was launched in 2014 to raise awareness of road safety issues and to campaign for prevention measures to be put in place to reduce RTC deaths and disability.[33]

As with all public health and health promotion strategies, the best impact can be gained through synergistic multidimensional interventions: through policy, legislation, environmental modification, public education, and motivation.[35] To best select the priorities for RTC prevention in Botswana and Zambia, there are three cardinal features to consider: (1) making basic structural changes to places, (2) that are scalable to large populations, and (3) have reasonable sustainability.[36] For example, in urban areas, the use of speed bumps in roads can reduce traffic flow and vehicle speed to effectively prevent injury, especially for pedestrians.[36,37] A recent study in Ghana showed that the placement of speed bumps reduced RTC fatalities by half, especially when installed near hazardous intersections or pedestrian crossings.[38] Every $1USD invested in speed bumps can return as much as $200USD in savings, making this a cost-effective intervention.

Despite the limitations of our approach, our results in Botswana and Zambia reflect on the urgent need for road safety. First, Granger causality is not the most robust test of causation: even Granger suggested a better term may be "temporally related."[39] Even so, our objective with this research was to foster an appreciation that traffic-related mortality may not simply co-occur with economic development. In the absence of appropriate safety measures, RTC mortality is one of its products. The data have limitations too. Specifically for Botswana, RTC injury patients who survive until presentation to a hospital but die later may not be recorded as fatalities.[40] We expect this issue occurs in Zambia too, and that in both countries, fatalities in rural areas may go unreported. Thus we expect that the data we used underestimate the incidence of RTC fatalities. We chose to use Zambia for comparison given its geographic proximity to Botswana and because it did not undergo the same rate of economic development as did Botswana over the past four decades. Although South Africa and Namibia also border Botswana and thus were potential candidates, they were economically developed relative to Botswana during the study period and thus not chosen for comparison. Angola and Zimbabwe neighbour Botswana and Zambia, but Angola's oil production and mineral extraction have contributed to economic development, and Zimbabwe has experienced political unrest, a large external debt, and economic decline. Both countries have experienced recent political and economic instability, making them poor candidates for comparison.[41] A complicating factor is that RTC fatality rates are also influenced by the availability of pre-hospital emergency services,[42] which while not robust are more developed in Botswana than in Zambia.[43] Perhaps, then, EMS in Botswana has reduced rates of RTC fatalities. This may have caused bias towards the null and prevented us from observing an even stronger relationship between GDP and RTC mortality in Botswana. Developing injury surveillance systems with greater geographic coverage will enable more comprehensive analyses.

The WHO Decade of Action for Road Safety 2011–2020 is underway, with the goal of preventing five million road traffic deaths globally by 2020. As a result, countries worldwide will be prioritising opportunities to improve road safety improvements in addition to fostering economic development. As reported in the WHO Training Manual on Road Safety, the evidence for what works has been demonstrated, and must

now be prioritised in action plans and strategies.[44] A country that is developing should allocate funding for public safety including protection measures on the roads. This is not guaranteed, and will only happen with political will and consumer pressure, led by public health scrutiny, ensuring that regulation and policy planning accompany economic growth.

Conflicts of interest

The authors have no conflicts of interest to declare.

Author contribution

DW and CB conceived the study idea, collected the data and conducted the analysis. DW and CB drafted the manuscript; SR provided public health input; SR, TM, and KC provided guidance and edited drafts of the manuscript. All authors contributed edits to prepare revised versions of the manuscript.

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