Journal of Public Health Advance Access published August 25, 2015

Journal of Public Health | pp. 1–7 | doi:10.1093/pubmed/fdv111

Impact of homicide and traffic crashes on life expectancy in the largest Latin American country

Nathalie Auger[1,2], Emilie Le Serbon[1,3], Davide Rasella[4], Rosana Aquino[4], Maurício L. Barreto[4]

[1]Institut national de santé publique du Québec, Montreal, QC, Canada
[2]University of Montreal Hospital Research Centre, Montreal, QC, Canada
[3]Institut de Démographie de l'Université Paris 1, Université Panthéon-Sorbonne, Paris, France
[4]Institute of Collective Health, Federal University of Bahia, Salvador, Brazil
Address correspondence to Nathalie Auger, E-mail: nathalie.auger@inspq.qc.ca

ABSTRACT

Background Brazil and Canada are on opposite poles of the spectrum for life expectancy in America. We identified factors underlying Brazil's lower life expectancy relative to Canada, with emphasis on the role of injury compared with other major causes.

Methods We computed life expectancy at birth in Brazil and Canada in 2010 and identified the ages and causes of death responsible for the gap between both countries. The main outcome measure was the contribution of homicide and traffic accidents to the gap, compared with other causes of death.

Results Relative to Canada, life expectancy was lower in Brazil by 8.2 years (men) and 5.2 years (women). Injury lowered life expectancy of men in Brazil by 2.2 years, or more than a quarter of the gap, mainly due to homicide and traffic accidents between ages 20 and 64 years. Homicide and traffic accidents contributed more than all circulatory diseases combined. In women, circulatory disease was the most important cause of lower life expectancy.

Conclusions In 2010, homicides and traffic accidents were the principal cause for short life expectancy of men in Brazil. Improving life expectancy in Brazil requires addressing the root causes of inequalities that drive illicit drug trade, violence and accidents.

Keywords accidents, traffic, Brazil, Canada, homicide, life expectancy, mortality, violence

Introduction

Brazil is the largest middle income country in Latin America and is an emerging economic powerhouse.[1] Yet, Brazil is among countries with the highest socioeconomic inequalities in the world,[2] and life expectancy continues to lag behind North America, especially Canada.[3,4] Although there are signs that Brazil's health is improving due to a reduction in infectious diseases,[5] and social and health reforms with declining child mortality,[1,2,6] many challenges remain, including a high burden of mortality from injury. Violence and accidents are overlooked compared with problems such as circulatory disease.[7,8] Homicide and traffic accidents are emerging as important causes of mortality in Brazil,[9,10] but the impact on life expectancy is poorly understood.

Evaluating how life expectancy is affected by injury compared with other causes of death is a first step in rectifying this knowledge gap. Our objective was to determine to which extent homicide, traffic accidents and other injuries lowered the life expectancy of men and women in Brazil, relative to other causes of death. We compared Brazil with Canada, the country with the highest life expectancy in America,[3,4] and a low rate of homicide.[11] These two countries are at different levels of socioeconomic development, yet both have a history of colonization with unique political contexts. Comparison

Nathalie Auger, Professor of Public Health and Epidemiology
Emilie Le Serbon, Demographer
Davide Rasella, Researcher in Epidemiology
Rosana Aquino, Associate Researcher
Maurício L. Barreto, Professor of Epidemiology

with Canada provides an ideal scenario to identify possible targets for increasing life expectancy in Brazil.

Methods

Data sources and causes of death

We obtained data on all deaths, births and population counts in 2010 for men and women in Brazil and Canada from the Brazil Ministry of Health and Statistics Canada.[12,13] Data were available for infants <1 year, children 1–4 years, and every 5-year age group thereafter up to 80 years. In Brazil, 80 years and over is the last age group for which data were publicly available at the time of the study.[12] Age at death was not known for 3308 men (0.5%) and 474 women (0.1%) in Brazil whom we could not include in analyses. Similarly, sex was unknown for 442 births in Brazil (0.02%).

The principal cause of death was identified using the 10th revision of the International Classification of Diseases (ICD).[14] We aggregated very rare causes of death, resulting in 17 main categories for analysis. These included injury (V01-Y98), circulatory (I00-I99), respiratory (J00-J99), tumour (C00-D48), infectious (A00-B99), endocrine (E00-E90), digestive (K00-K93), nervous and mental (F00-G99), genitourinary (N00-N99), musculoskeletal (M00-M99), integument (L00-L99), eye and ear (H00-H95), blood (D50-D89), maternal (O00-O99), perinatal (P00-P96), congenital anomaly (Q00-Q99) and ill-defined diseases (R00-R99).

We also sought to determine which specific causes of death were involved in reducing life expectancy. For injuries, we assessed homicide by firearm (X95), stabbing (X99), and other methods (X85-X94, X96-X98, Y00-Y09), traffic crashes (V01-V99), falls (W00-W19), other accidents such as drowning, poisonings and burns (W20-X59), suicide (X60-X84) and all remaining injuries. For circulatory diseases, we assessed cerebrovascular (I60-I69), hypertensive (I10-I15), ischaemic heart (I20-I25), non-ischaemic heart (I26-I52) and all remaining circulatory diseases. A complete list of specific causes and ICD codes for the other categories of death is provided in Supplementary data, Table S1.

Statistical analysis

We calculated mortality rates by age and cause, directly standardized using the 2010 Brazil population as reference. We computed life expectancy at birth with 95% confidence intervals (CI) for men and women,[15] and the absolute difference in life expectancy between Brazil and Canada.

To determine the age groups and causes of death responsible for lowering the life expectancy of Brazil relative to Canada, we used Arriaga's decomposition approach[16] with Monte Carlo simulations for 95% CIs.[17] Arriaga's method partitions the life expectancy gap between Brazil and Canada into smaller units. Arriaga's decomposition yields the exact number of years life expectancy is lost in Brazil due to each cause and age group, relative to Canada.

To illustrate Arriaga's method, consider a scenario where life expectancy in Brazil is 10 years lower than Canada, with mortality arising from only three age groups (<20, 20–44 and ≥45 years) and three causes (injury, circulatory and respiratory). Suppose that after partitioning the 10-year gap using Arriaga's method, we find that the age groups <20, 20–44 and ≥45 accounted for 7, 1 and 2 years of the gap, respectively. The sum of all these contributions equals the total life expectancy gap ($7 + 1 + 2 = 10$ years). In this example, Brazilians aged <20 lowered life expectancy by 7 years, whereas Brazilians aged ≥20 only lowered life expectancy by 3 years ($1 + 2 = 3$ years). Thus, mortality in Brazilians aged <20 was responsible for 70% of the life expectancy gap, indicating that improvements in longevity could be achieved primarily by reducing mortality of children and youth.

Consider a more complicated scenario in which Brazil has higher mortality from injury and circulatory diseases than Canada, but lower mortality from tumours. After applying Arriaga's method, we find that injury reduced life expectancy in Brazil by 9 years and circulatory disease by 3 years. We find, however, that tumours reduced life expectancy in Canada by 2 years, an impact that helped bridge the gap with Brazil. The sum of all these contributions again equals the total life expectancy gap ($9 + 3 - 2 = 10$ years). In this last example, we can conclude that a major reduction in injury mortality is required to improve life expectancy in Brazil. We can even infer that Brazil's low tumour mortality helped mask the full impact of injuries on life expectancy relative to Canada.

Arriaga's method is advantageous for its ability to identify the exact ages and causes to prioritize for improving life expectancy. This approach does not require a reference population, a limitation of standardized mortality rates that can affect the ranking of causes of death in country comparisons.[18] Arriaga's method answers a different question than studies addressing burden of disease, where measures such as disability-adjusted life years report on the number of years lost due to poor health,[19] rather than the exact impact on life expectancy. Arriaga's method also complements regression-based analyses that yield relative risks or odds ratios, measures of association that do not quantify the actual amount of life expectancy lost due to a given cause or age.

Data analyses were carried out using Arriaga's macro in SAS version 9.2.[20] In sensitivity analyses, we verified that redistribution of live births with unknown sex did not impact the results. The Institutional Review Board of the University

of Montreal Hospital Centre provided a waiver from ethics review, as the data were publicly available and de-identified, conforming to regulations for ethical conduct of research involving humans in Canada.

Results

In 2010, men had a life expectancy of 71.63 years in Brazil (95% CI: 71.59, 71.67) and 79.86 years in Canada (95% CI: 79.80, 79.93). Life expectancy for women was 79.35 years in Brazil (95% CI: 79.32, 79.39) and 84.51 years in Canada (95% CI: 84.45, 84.57). The life expectancy gap between Brazil and Canada was wider for men (8.24 years, 95% CI: 8.16, 8.31) than for women (5.16 years, 95% CI: 5.09, 5.23).

Mortality in Brazil was higher at all ages compared with Canada (Table 1). Nonetheless, mortality of young men was more heavily implicated in reducing life expectancy than mortality of older men in Brazil. Mortality of men aged 20–64 lowered life expectancy by 4.9 years, or 58.9% of the gap relative to Canada. In contrast, mortality of young women had a smaller impact, reducing life expectancy by 2.1 years in Brazil. Mortality of individuals aged 65–79 lowered life expectancy by smaller amounts (men 1.6 years and women 1.5 years). Thus, early mortality of young adult men explained more than half of the 8.2 year gap between Brazil and Canada, in contrast to young women whose lower mortality led to a smaller 5.2 year gap.

Table 1 Contribution of age to loss in life expectancy, Brazil versus Canada, 2010

	Mortality rate[a]		*Contribution to life expectancy gap, years (95% CI)*	*Percent of gap*
	Brazil	*Canada*		
Men				
<1	1608	549	0.77 (0.76, 0.78)	9.4
1–19	81	24	0.69 (0.69, 0.70)	8.4
20–44	311	95	2.44 (2.43, 2.45)	29.6
45–64	1009	487	2.41 (2.40, 2.43)	29.3
65–79	3666	2352	1.64 (1.62, 1.65)	19.9
≥80	11 063	10 255	0.28 (0.27, 0.30)	3.4
Total	753	443	8.24 (8.16, 8.31)	100
Women				
<1	1312	456	0.68 (0.67,0.69)	13.1
1–19	38	15	0.33 (0.32,0.33)	6.3
20–44	106	50	0.71 (0.70, 0.72)	13.8
45–64	539	310	1.34 (1.33, 1.35)	26.0
65–79	2334	1522	1.53 (1.52, 1.55)	29.7
≥80	9257	8479	0.57 (0.55, 0.59)	11.1
Total	456	310	5.16 (5.09, 5.23)	100

[a]Mortality rate per 100 000, directly standardized using the 2010 population of Brazil as reference.

In Brazil, injury for men was not as important a cause of mortality as circulatory diseases (Table 2). Men had 126 injury deaths versus 205 circulatory deaths per 100 000. There were, however, fewer deaths from tumours (113 per 100 000) compared with injury. Women in contrast had low rates of injury mortality, close to levels seen in Canada.

Despite high mortality from circulatory diseases, injury was the principal cause for the low life expectancy of men in Brazil (Table 2). In 2010, men lost 2.2 years of life expectancy due to injury compared with 2.0 years due to circulatory diseases, relative to Canada. For women, injuries lowered life expectancy by only 0.1 years, a negligible amount compared with circulatory diseases that contributed 2.2 years. Thus, the lower life expectancy of men in Brazil compared with women was largely due to injury mortality.

Almost a fifth of deaths in Brazilian men were caused by injury (18.0%). Of these, 40.2% were homicides and 30.6% traffic crashes (Fig. 1). Nearly three-quarters (72.7%) of homicides were by firearm, with stabbings accounting for most of the remainder (15.2%). In comparison, injuries represented less than a tenth of all deaths to men in Canada (8.5%), and of these only 3.7% were homicides (37.4% of which occurred with firearms). In women, only 5.1% of deaths were caused by injury. Homicides nonetheless accounted for 17.7% of these deaths, and accidents 61.4%.

In 2010, homicide by firearm was the single most important cause that lowered life expectancy of men in Brazil (Fig. 2 and Supplementary data, Table S1). Firearm homicides lowered life expectancy by 1.03 years, stabbings by 0.19 years, and other homicides by 0.15 years, together accounting for 1.38 years lost relative to Canada. Cerebrovascular disease was the second most important (0.94 years), followed by traffic crashes (0.75 years). Injury in men aged 20–44 years was the largest contributing age group. Homicide at ages 20–44 decreased life expectancy by 0.72 years (95% CI: 0.71, 0.73) and traffic crashes by 0.45 years (95% CI: 0.43, 0.46). Homicide in men aged <20 decreased life expectancy by an additional 0.27 years (95% CI: 0.26, 0.27). Suicide was the only form of injury that impacted Canada more than Brazil, lowering life expectancy of men in Canada by 0.21 years, an amount similar to stabbings in Brazil.

In women, injury was less implicated in reducing life expectancy. Women had similar contributions from traffic crashes and homicides (0.14 and 0.12 years of life expectancy lost relative to Canada, respectively). The main factors that reduced life expectancy of women were instead cerebrovascular (0.96 years) and hypertensive (0.69 years) diseases, pneumonia (0.77 years) and diabetes (0.74 years). These same

Table 2 Contribution of major causes to loss in life expectancy, Brazil versus Canada, 2010

	Men				*Women*			
	Mortality rate[a]		*Contribution to life expectancy gap, years (95% CI)*	*Percent of gap*	*Mortality rate*[a]		*Contribution to life expectancy gap, years (95% CI)*	*Percent of gap*
	Brazil	*Canada*			*Brazil*	*Canada*		
Injury	126.1	50.7	2.18 (2.15, 2.20)	26.4	24.4	22.0	0.09 (0.07, 0.11)	1.7
Circulatory	205.2	117.4	2.01 (1.98, 2.05)	24.5	142.6	76.6	2.21 (2.17, 2.25)	42.8
Respiratory	76.6	35.9	0.98 (0.96, 1.00)	11.9	51.2	23.9	1.07 (1.04, 1.09)	20.7
Tumour	113.4	135.9	−0.45 (−0.49, −0.42)	−5.5	79.1	102.3	−0.90 (−0.93, −0.86)	−17.4
Infectious	32.1	9.7	0.60 (0.59, 0.61)	7.3	19.7	6.9	0.45 (0.44, 0.47)	8.8
Endocrine	42.4	17.5	0.46 (0.45, 0.48)	5.6	35.9	11.8	0.87 (0.86, 0.89)	16.9
Digestive	37.6	17.6	0.61 (0.60, 0.63)	7.4	19.8	12.2	0.25 (0.23, 0.27)	4.9
Nervous-Mental	24.7	33.7	−0.15 (−0.17, −0.14)	−1.9	15.5	33.0	−0.79 (−0.81, −0.76)	−15.2
Genitourinary	14.9	8.6	0.15 (0.14, 0.16)	1.8	11.3	6.8	0.15 (0.14, 0.16)	2.9
Musculoskeletal	1.8	1.7	0 (0, 0.01)	0.0	2.9	2.6	0.01 (0, 0.01)	0.1
Integument	1.7	0.6	0.03 (0.02, 0.03)	0.3	1.7	0.6	0.04 (0.04, 0.05)	0.8
Eye and Ear	0.1	0.0	0 (0, 0)	0.0	0.1	0.0	0 (0, 0)	0.0
Blood	3.7	1.6	0.06 (0.05, 0.06)	0.7	3.0	1.4	0.06 (0.05, 0.06)	1.1
Maternal					1.8	0.2	0.05 (0.05, 0.06)	1.0
Perinatal	13.8	4.6	0.47 (0.47, 0.48)	5.7	11.0	3.9	0.39 (0.38, 0.40)	7.6
Congenital anomaly	5.6	3.1	0.13 (0.12, 0.14)	1.6	5.0	2.5	0.14 (0.13, 0.15)	2.7
Ill defined	53.2	4.7	1.15 (1.13, 1.16)	14.0	31.3	3.9	1.06 (1.04, 1.08)	20.5
Total	753	443	8.24 (8.16, 8.31)	100	456	310	5.16 (5.09, 5.23)	100

[a]Mortality rate per 100 000, directly standardized using the 2010 population of Brazil as reference.

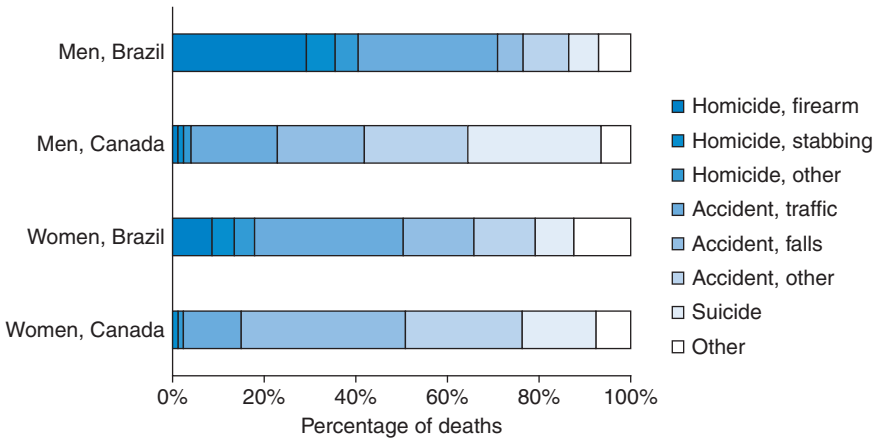

Fig. 1 Distribution of injuries according to cause, Brazil and Canada, 2010. In men, there were 116 349 injury deaths in Brazil and 10 252 in Canada. In women, there were 24 769 injury deaths in Brazil and 6001 in Canada.

causes also lowered the life expectancy of men, but to a lesser degree than injury. It is noteworthy that ischaemic heart disease reduced life expectancy in both countries, but much of the mortality in Brazil occurred before age 80 years.

The impact of other specific causes of death, many of which share proximal risk factors with injury, was less striking (Supplementary data, Fig. S1). In 2010, HIV, tuberculosis and other infections in Brazil reduced the life expectancy of both men and women. Alcohol-related diseases were prominent in men; mortality due to liver disease reduced life expectancy by 0.36 years, and alcohol-related nervous-mental disorders by 0.12 years. Maternal mortality lowered life expectancy of

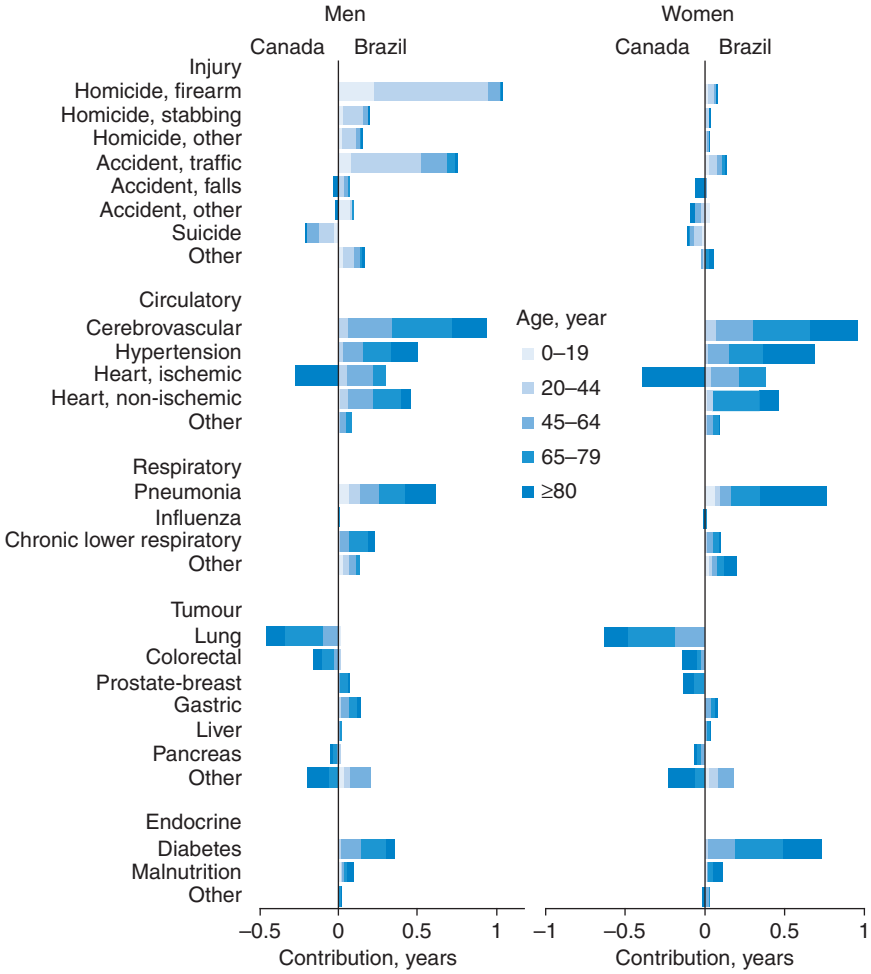

Fig. 2 Contribution of major causes of death to loss in life expectancy, Brazil versus Canada, 2010. Bars to the right of the axis led to a reduction of life expectancy in Brazil, and bars to the left a reduction of life expectancy in Canada.

women by 0.05 years, with 19.5% of the reduction occurring before age 20. These findings contrast with dementia and tumours, causes that lowered Canada's life expectancy relative to Brazil. Mortality rates for specific causes of death are shown in Supplementary data, Table S1.

Discussion

Main finding of this study

We evaluated the impact of injury mortality in 2010 on life expectancy in Brazil relative to Canada. We found that injury mortality in men was the single largest cause for Brazil's lower life expectancy. In Brazil, men lived 8.2 years less than in Canada, with injury accounting for 2.2 years of this gap. Despite signs of improvement in the 2000s,[10,21] homicide and traffic crashes in 2010 were still leading injuries that shortened longevity. The contribution from homicide alone was more important than cerebrovascular disease, a significant finding as mortality rates for circulatory diseases are high in Brazil.[7] Mortality due to homicide and traffic accidents is only the tip of the iceberg, as most injuries cause disability and economic losses that are difficult to quantify yet more prevalent.[9,10,22] These findings highlight the major role of injury in the lives of Brazilians, especially men. Most of the loss in life expectancy occurred at young ages and involved firearms, a preventable cause of death.

What is already known on this topic

After introducing a unified health system in the 1990s followed by other social reforms including conditional cash transfers to families in poverty,[1,2] Brazil has seen improvements in cardiovascular disease,[23] infant mortality[6,24] and life expectancy.[25] Although these programmes are commendable for their positive socioeconomic and health impacts, their ability to prevent homicide and traffic accidents is less clear. Injury results from a complex set of social determinants, which are difficult for health systems to tackle without additional laws specific to

injury. There is evidence, for instance, that alcohol use behind the wheel declined after Brazil enacted a law criminalizing drinking and driving in 2008.[26] Gun legislation introduced in 2003 is estimated to have prevented 5000 homicides the following year alone.[27] Homicide rates in the slums of urban areas are particularly high and exacerbated by conditions that compound violence,[28] such as income inequality,[25] drug trafficking, weapons smuggling and organized crime.[10,29] Substance use exacerbates problems of violence,[10] and clusters with injuries presenting to emergency departments in Brazil.[30] Alcohol in particular is prevalent and consumption may be rising.[1,31] Furthermore, alcohol consumption is a risk factor for traffic accidents.

What this study adds

Brazil is known for high rates of homicide and traffic-related mortality,[9,10] but the impact on life expectancy has not previously been investigated. In this study, we show that the life expectancy gap between Brazil and Canada was larger for men than women, and that injuries were the reason. Even though circulatory disease in Brazil was a more common cause of death in men, injuries accounted for more years of life expectancy lost relative to Canada. Nearly three-quarters of deaths due to injury were homicides and traffic crashes, and most occurred in young men. Thus this study's novel contribution is to show just how much injury was responsible for lowering the life expectancy of Brazilian men. Past studies that report only rates highlight the problem of injuries in Brazil,[9,10] but underestimate the actual impact on life expectancy. Thus, the role of injuries in lowering life expectancy of Brazilian men needs much greater attention in research and policy.

Our findings point to the importance of focusing on policies with potential to reduce injuries. Declines in traffic-related deaths were observed after Brazil enacted a 1998 Traffic Code,[10] but mortality rates are still elevated and strategies to cut alcohol consumption may be needed to tackle rates further. Legislation of the aggressive marketing and promotion tactics of the alcohol and gun industries may also be helpful,[2,27] in much the same way that Brazil curtailed tobacco consumption through antismoking reform.[30] Although such tasks may seem daunting, a simple first step might be to increase funding for research on injury. Brazil devotes only 0.9% of funding to research on violence, accidents and trauma,[8] an amount far from the 27% reduction in life expectancy caused by injury. Including millennium development goals for violence and accidents might help draw more attention to the burden of injury.[2]

Limitations of this study

This study should be interpreted in light of limitations common to ecologic analyses. We used aggregated data that prevent inference to individuals. There may be differences in quality and comparability of coding of cause of death between Brazil and Canada. Brazil used ill-defined disease codes more frequently, suggesting that we may have underestimated contributions from some causes. Estimates of injury mortality in Brazil have, however, been shown to be reliable.[32] Accuracy of life expectancy estimates is lowered by the last age group available (80 years). Finally, Arriaga's method can underestimate the contribution of causes more common in older age groups.[20] This problem does not affect estimates for injury as most were concentrated at younger ages.

Conclusions

In this study, injury mortality had a larger impact on reducing life expectancy of Brazilian men than circulatory disease. The toll of homicide and traffic crashes on life expectancy is large, but is masked by high rates of circulatory disease mortality. Brazil has the potential to increase life expectancy by reducing injury mortality in young men to levels nearer to Canada, where low rates of homicide and traffic crashes set a standard. Research is needed to identify strategies for reducing homicide and traffic crashes in Brazil. It is unlikely that life expectancy in Brazil will increase significantly without stronger preventive strategies to reduce injury in young men.

Supplementary data

Supplementary data is available at *PUBMED* online.

Acknowledgements

The authors thank Tara Dourian for research assistance.

Funding

This work was supported by the University of Montreal Hospital Research Centre. N.A. acknowledges a career award from the Fonds de recherche du Québec-Santé.

References

1 Paim J, Travassos C, Almeida C *et al*. The Brazilian health system: history, advances, and challenges. *Lancet* 2011;**377**:1778–97.

2 Victora CG, Barreto ML, do Carmo Leal M *et al*. Health conditions and health-policy innovations in Brazil: the way forward. *Lancet* 2011;**377**:2042–53.

3 2014 Human Development Statistical tables [Internet]. United Nation Development Programme, 2014. http://hdr.undp.org/en/data (3 December 2014, date last accessed).

4 World Health Statistics 2014 [Internet]. World Health Organization, 2014. http://apps.who.int/iris/bitstream/10665/112738/1/9789240692671_eng.pdf?ua=1 (3 December 2014, date last accessed).

5 Barreto ML, Teixeira MG, Bastos FI *et al*. Successes and failures in the control of infectious diseases in Brazil: social and environmental context, policies, interventions, and research needs. *Lancet* 2011;**377**:1877–89.

6 Rasella D, Aquino R, Santos CA *et al*. Effect of a conditional cash transfer programme on childhood mortality: a nationwide analysis of Brazilian municipalities. *Lancet* 2013;**382**:57–64.

7 de Fatima Marinho de Souza M, Gawryszewski VP, Orduñez P *et al*. Cardiovascular disease mortality in the Americas: current trends and disparities. *Heart* 2012;**98**:1207–12.

8 Pacheco Santos LM, Moura EC, Barradas Barata Rde C *et al*. Fulfillment of the Brazilian agenda of priorities in health research. *Health Res Policy Syst* 2011;**9**:35.

9 Murray J, Cerqueira DR, Kahn T. Crime and violence in Brazil: systematic review of time trends, prevalence rates and risk factors. *Aggress Violent Behav* 2013;**18**:471–83.

10 Reichenheim ME, de Souza ER, Moraes CL *et al*. Violence and injuries in Brazil: the effect, progress made, and challenges ahead. *Lancet* 2011;**377**:1962–75.

11 Homicide in Canada, 2013 [Internet]. Statistics Canada, 2014. http://www.statcan.gc.ca/daily-quotidien/141201/dq141201a-eng.pdf (3 December 2014, date last accessed).

12 Brazil Ministry of Health [Internet]. Datasus, 2014. http://www2.datasus.gov.br/DATASUS/index.php?area=02 (10 October 2014, date last accessed).

13 Statistics Canada [Internet]. Cansim, 2014. http://www5.statcan.gc.ca/cansim/home-accueil?lang=eng (10 October 2014, date last accessed).

14 International Classification of Diseases, 10th revision [Internet]. World Health Organization, 2014. http://apps.who.int/classifications/icd10/browse/2015/en (10 October 2014, date last accessed).

15 Chiang CL. *The Life Table and its Applications*. Malabar: Robert E. Krieger Publishing Company, 1984.

16 Arriaga EE. Measuring and explaining the change in life expectancies. *Demography* 1984;**21**:83–96.

17 Robert CP, Casella G. *Monte Carlo Statistical Methods*. New York: Springer, 2010.

18 Ahmad OB, Boschi-Pinto C, Lopez AD *et al*. Age standardization of rates: a new WHO standard [Internet]. World Health Organization, 2001. http://www.who.int/healthinfo/paper31.pdf (10 November 2014, date last accessed).

19 Murray CJ, Vos T, Lozano R *et al*. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;**380**:2197–223.

20 Auger N, Feuillet P, Martel S *et al*. Mortality inequality in populations with equal life expectancy: Arriaga's decomposition method in SAS, Stata, and Excel. *Ann Epidemiol* 2014;**24**:575–80.

21 Lotufo PA, Bensenor IM. Income inequality and male homicide rates: Sao Paulo, Brazil, 1996–2007. *Eur J Public Health* 2009;**19**:602–4.

22 Williams DJ, Donnelly PD. Is violence a disease? Situating violence prevention in public health policy and practice. *Public Health* 2014;**128**:960–7.

23 Cabral NL, Franco S, Longo A *et al*. The Brazilian Family Health Program and secondary stroke and myocardial infarction prevention: a 6-year cohort study. *Am J Public Health* 2012;**102**:e90–5.

24 Guanais FC. The combined effects of the expansion of primary health care and conditional cash transfers on infant mortality in Brazil, 1998–2010. *Am J Public Health* 2013;**103**:2000–6.

25 Rasella D, Aquino R, Barreto ML. Impact of income inequality on life expectancy in a highly unequal developing country: the case of Brazil. *J Epidemiol Community Health* 2013;**67**:661–6.

26 Moura EC, Malta DC, Morais Neto OL *et al*. Motor vehicle driving after binge drinking, Brazil, 2006 to 2009. *Rev Saude Publica* 2009;**43**:891–4.

27 Marinho de Souza Mde F, Macinko J, Alencar AP *et al*. Reductions in firearm-related mortality and hospitalizations in Brazil after gun control. *Health Aff (Millwood)* 2007;**26**:575–84.

28 Szwarcwald CL, da Mota JC, Damacena GN *et al*. Health inequalities in Rio de Janeiro, Brazil: lower healthy life expectancy in socioeconomically disadvantaged areas. *Am J Public Health* 2011;**101**:517–23.

29 2011 Global study on homicide [Internet]. United Nations Office on drugs and crime, 2014. http://www.unodc.org/documents/data-and-analysis/statistics/Homicide/Globa_study_on_homicide_2011_web.pdf (4 December 2014, date last accessed).

30 Gawryszewski VP, da Silva MM, Malta DC *et al*. Violence-related injury in emergency departments in Brazil. *Rev Panam Salud Publica* 2008;**24**:400–8.

31 Schmidt MI, Duncan BB, Azevedo e Silva G *et al*. Chronic non-communicable diseases in Brazil: burden and current challenges. *Lancet* 2011;**377**:1949–61.

32 Bhalla K, Harrison JE, Shahraz S *et al*. Availability and quality of cause-of-death data for estimating the global burden of injuries. *Bull World Health Organ* 2010;**88**:831–8C.