Estimating injury mortality in South Africa and identifying urban-rural differences

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Plagiarism Declaration

I, Megan Renay Prinsloo, hereby declare that the work on which this thesis is based is my own original work, (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed: Signed by candidate

Date: 16 March 2019

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LIST OF ABBREVIATIONS

ASR – age-standardised rate

AIC – Akaike Information Criterion

BIC – Bayesian Information Criterion

CI – confidence interval

DoH – Department of Health

DoT – Department of Transport

GBD – Global Burden of Disease

GLM – Generalized Linear Modelling

ICD-10 – International Classification of Diseases and Related Health Problems version 10

IMS – Injury Mortality Survey

IRR – incidence rate ratio

IRRR – interaction relative risk ratio

MCA – Multiple Correspondence Analysis

metro – metropolitan

NBD – National Burden of Disease

NIMSS – National Injury Mortality Surveillance System

non-metro – non-metropolitan

RRR – relative risk ratio

RTMC – Road Traffic Management Corporation

SAPS – South African Police Service

SDGs – Sustainable Development Goals

Stats SA – Statistics South Africa

WHO – World Health Organization

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ABSTRACT

The overarching aim of this thesis is to utilise national data on injury mortality in South Africa, to conduct advanced statistical analyses to identify urban-rural differences for injury deaths, and to gain insight into the explanatory variables for homicide in metropolitan- and non-metropolitan (metro- and non-metro) areas.

The literature review describes the global and national estimates of injury mortality and reports higher rural than urban injury mortality rates for high-income countries. It further discusses a framework for assessing data quality and reviews South Africa's fatal and non-fatal injury data sources, issues of under-reporting and misclassification of deaths. The risk factors for violence are reviewed, which inform particular hypotheses on the role of age, sex, race, day of week and firearms with regard to homicide.

The Injury Mortality Survey (IMS) data, which estimated 52 493 injury deaths nationally in 2009, is utilised for this PhD study. Data quality is assessed using an internationally developed conceptual framework for mortality data. Exploratory and multiple correspondence analysis identified possible associations between metro/non-metro and other explanatory variables, prior to more sophisticated multinomial logistic regression analysis, which adjusted for age, sex, race and metro/non-metro for each manner of death (homicide, suicide, transport-related and other unintentional injury deaths) to explore particular hypotheses for the differences in the metro/non-metro injury mortality profile. Age-standardised injury mortality rates were calculated to take into account the effects of different age structures for metro- and non-metro populations. Generalized linear models were fitted in relation to particular hypotheses to determine the explanatory variables for homicide deaths in both metro and non-metro areas.

Main findings include a significantly higher likelihood for homicide in metro areas compared to non-metro areas, while transport-related deaths were significantly lower in metro areas. The risk of homicide for Coloureds was higher than Blacks in metro areas, while Blacks, Coloureds and Asians had similar risks of homicide in non-

metro areas. Whites had a similar risk and Asians a higher risk of homicide in non-metro areas compared with metro areas. Firearm use was shown to significantly explain metro/non-metro differences in homicide risks.

This study's most significant knowledge contribution includes the identification of metro/non-metro as a significant predictor of the injury mortality profile in South Africa. The association of metro/non-metro differences in the pattern of homicide for Blacks and Coloureds, also resolved conflicting statements found in the literature regarding race and homicide in South Africa. The results are of considerable significance to national and provincial policy makers. Recommendations are made in relation to the main findings of this study.

1 INTRODUCTION

1.1 Background

Injuries are predictable and largely preventable, yet globally more than 14 000 people lose their lives every day due to the various causes of injury (WHO, 2014a). Approximately 5 million injury deaths[1] occur annually, with road traffic injury accounting for one quarter of deaths and another quarter for suicide and homicide. Road traffic injuries are predicted to rise in rank from the 9th to the 7th leading cause of death between 2012 and 2030, after largely non-communicable diseases such as ischaemic heart disease, stroke, diabetes and lung cancer among others (WHO, 2014a). Non-fatal injuries amount to approximately 970 million globally (Haagsma et al., 2015), resulting in informal treatment, primary health care, emergency medical care or hospitalization (WHO, 2014a). Many of those physically injured result in short-term, long-term or lifelong disability.

Injuries are a particular public health problem in low- and middle-income countries, where more than 90% of injuries occur globally (WHO, 2010b, 2014a), with homicide leading the injury mortality profile (WHO, 2017a). In 2000, homicide and road traffic injuries were the second and fourth leading causes of death for South Africa. The country is experiencing a quadruple burden of disease from non-communicable diseases (i.e. cardiovascular disease and cancer), HIV/AIDS and tuberculosis, other communicable diseases/maternal conditions/perinatal conditions and injuries (Bradshaw et al., 2003; Pillay-van Wyk et al., 2016a). The rates for homicide and road traffic injury deaths in 2000, were seven times and double the global average respectively (Norman, Matzopoulos, Groenewald, & Bradshaw, 2007). WHO estimates indicate that global homicide declined by 16% between 2000 and 2012. High-income countries had a more distinctive decline of 39%, while declines of 10%-13% were noted for low- to middle-income countries (Butchart, Mikton, & Krug, 2014).

South Africa's homicide rate declined by 52% between 1997 and 2012 (Msemburi et al., 2016; Pillay-van Wyk et al., 2016a), yet at 38.4 per 100 000

[1] The words 'death' and 'mortality' are interchangeably used throughout this thesis.

population (Matzopoulos et al., 2015), it remains nearly six times the global rate of 6.4 per 100 000 (WHO, 2017b). The decline in homicide rates have been attributed to the decline in firearm violence (Matzopoulos, Thompson, & Myers, 2014), following the implementation of the Firearms Control Act (Firearms Control Act, 2004) and was also attributed to political stabilization within the South African society (Matzopoulos et al., 2014). The South African Police Service (SAPS) statistics indicate however, that there has been an annual increase in homicide since the 2011/2012 financial year (SAPS, 2017a).

1.2 The impact of South Africa's history on violence

The homicide rate is highest for the South African youth (Norman et al., 2007; Matzopoulos et al., 2015), mainly affecting those who are unemployed, poorly educated and who live under impoverished conditions. These conditions are an effect of South Africa's history, which still influences today's society. From Dutch and British colonisation and slavery, to the years of Apartheid from 1948-1994 (Coovadia, Jewkes, Barron, Sanders, & McIntyre, 2009; Foster, 2012), during the years of resistance to segregation when many Black, Coloured and Asian youth were the victims of violent defeat, perpetrated by the Apartheid-ruling government (Foster, 2012). Violence even emerged during the 1800's during a period of socio-political change, as tribal conflicts between different ethnic groups in South Africa led to forced migration and large-scale murders to eliminate tribes. This was known as the "Mfecane" and occurred among tribes competing for natural resources and trade during a period of inequality and environmental crises (Eldredge, 1992). During the early 1900's, Black mine workers within the mining compounds started forming criminal gangs - the Zulu-based Ninevites gang, which operated in the mines and urban communities in the Witwatersrand in Johannesburg (Kynoch, 2008; Abrahams, 2010).

The segregation laws created during Apartheid led to forced removals and relocation of Black, Coloured and Asian people from their homes that were considered to be in areas allocated for Whites only[2]. The non-White population in South Africa were subjected to poor health and education systems, limited employment

[2] The socio-economic effects of Apartheid still impact on the health and welfare of today's society. Hence race is used as a proxy for socio-economic status and the terms 'Black', Coloured', 'Asian'/'Indian' and 'White' are used in the analysis of this thesis.

opportunities, segregation of transport systems and segregation of recreational public facilities.

The socio-economic factors such as unemployment, long-term poverty due to inequality and poor-quality education described previously are important factors that explain how youth are at risk of being drawn into crime, violence and gangs (Foster, 2012). Child maltreatment (Artz et al., 2016), exposure to high levels of intimate partner violence between parents (Abrahams & Jewkes, 2005) and in their own relationships (Jewkes, 2002; Abrahams, Mathews, Martin, Lombard, & Jewkes, 2013) are additional risk factors for violence in communities. SAPS statistics indicate that homicide occurred especially during social gatherings. Some of the motives included arguments or misunderstandings, domestic violence, gang conflict, retaliation or revenge attacks (SAPS, 2017a). Firearm availability is an additional risk factor, and has been associated with the high rate of homicide in South Africa (Matzopoulos et al., 2014; Matzopoulos et al., 2018). The risk factors for violence will be discussed in-depth in the literature review in Chapter 2.

Considering the above risk factors, it is possible that perpetrators and victims of violence have become accustomed to experiencing violence during their upbringing in poor communities. Policy interventions to reduce the level of violence will have to consider individual, relationship, community and societal factors that influence the risk of becoming a victim or perpetrator of violence. A global assessment of national efforts to address interpersonal violence found that national action plans rely on small-scale studies or implement plans without the required data (Butchart et al., 2014). The African region had the biggest gap between national action plans and available survey data for most types of violence. There was an emphasis on national action plans against sexual violence, intimate partner violence and child maltreatment, but only 30%-41% of countries reported plans to address youth violence, armed- and gang violence.

Interpersonal violence and road traffic injuries are major contributors to premature mortality in South Africa (Bradshaw et al., 2004; Norman et al., 2007; Msemburi et al., 2016; Pillay-van Wyk et al., 2016a) and should be deemed important public health problems. Trend estimates for South Africa's road traffic mortality do not reflect any substantial declines, with rates remaining relatively constant between

1997 and 2012 (Pillay-van Wyk et al., 2016b), and at 36.1 per 100 000 population these are nearly of the same magnitude as homicide (38.4 per 100 000) (Matzopoulos et al., 2015). Established road traffic safety interventions have led to declines in road traffic mortality for certain high-income countries, namely Australia, the United Kingdom (UK) and the United States of America (USA) (Peden, 2005). The fact that South Africa's rate for road traffic mortality has not shown a substantial decline should be cause for concern. The World Health Organization (WHO) attributes this to the speed of urbanization in developing countries, which has outpaced governments' ability to plan for appropriate land use, essential infrastructure and safe public transportation systems (WHO, undated).

In South Africa, road injuries are the second leading cause of death for children 5-14 years, after HIV/AIDS and rank third highest for the 15-44 year age group (Msemburi et al., 2016). The World Health Organization (WHO) lists four groups of risk factors for road traffic crashes (Peden, 2005). These include *factors that influence*:

- *exposure to risk*: economic and demographic factors, modes of transport, the level of motorization
- *crash involvement*: excessive speed, drinking and driving, vehicles that are no longer roadworthy, unsafe road design and the lack of effective law enforcement and safety regulations
- *crash severity*: no seat-belt use, child restraints or crash helmets, insufficient crash protection in- and outside of vehicles, human tolerance factors
- *severity of post-crash injuries*: delays in crash detection, delayed or poor emergency care or transport to health facilities, and inadequate trauma care and rehabilitation

These risk factors all contribute to the magnitude of road traffic injury deaths on South African roads. The *World Report on Road Traffic Injury Prevention* lists six recommendations to reduce the levels of road traffic injury deaths globally (Peden, 2004). This report was handed to government officials globally, on 07 April 2004 (World Health Day), and included the South African Minister of Health at the time (Peden, 2005). Yet there has been no substantial decline in road traffic injury deaths nationally. The South African Department of Health was however, mandated to develop an integrated strategic framework to prevent injury and violence in 2012 (Mayosi et al., 2012), aligned with the World Report on Violence and Health, which incorporates violence prevention legislation and policy, improvement of data

collection and research capacity, development of prevention responses and improvement of victim services (Krug, Dahlberg, Mercy, Zwi, & Lozano, 2002). The South African *2014-2019 Strategic Framework* has a National Development Plan 2030 vision, which states that by 2030, South Africans should have an increased life expectancy of at least 70 years, and that violence, accidents and other injuries should be reduced by 50% in comparison to 2010 levels, among other targets (National Department of Health, 2015). In order to meet these targets, and the United Nations Sustainable Development Goals to reduce injuries and violence globally (United Nations, 2015), the two leading causes of injury deaths require urgent public health initiatives to achieve substantial declines.

1.3 Sustainable Development Goals to reduce injuries and violence globally by 2030

The United Nations General Assembly adopted a resolution on 25 September 2015, where a 2030 agenda for Sustainable Development called for action by all countries to eradicate poverty, reduce mortality and to realize the human rights of all. This consisted of 17 Sustainable Development Goals (SDGs) and 169 targets (United Nations, 2015), of which some included: to end poverty, ensure quality education, sustain the management of available water and sanitation for all, build resilient infrastructure and to conserve the ocean and marine resources, among others. The SDGs were aimed at balancing the economic, social and environmental dimensions of sustainable development. The most important SDGs pertaining to the reduction of injury and violence include:

Goal 3: “Ensure healthy lives and promote well-being for all at all ages”

Target 3.6: “by 2020, halve the number of global deaths and injuries from road traffic accidents”

Goal 5: “Achieve gender equality and empower all women and girls”

Target 5.2: “eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation”

Goal 16: “Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels”

Target 16.1: to “significantly reduce all forms of violence and related death rates everywhere”

1.4 Challenges in data collection for South Africa

It is currently very challenging to monitor South Africa's progress towards achieving the SDG targets, as the country's vital registration data are flawed with issues of incomplete coverage of death registration and misclassification of deaths, in particular injuries and HIV (Bradshaw et al., 2011). Since 1998 there have been initiatives to improve coverage (Bah, 2009) and by 2007 this had improved to more than 80% (Bradshaw et al., 2011). The misclassification of deaths however, where more than 60% of South Africa's non-natural deaths are incorrectly reported as 'other unintentional', persists within the vital registration data reported by Statistics South Africa (Stats SA) (Bradshaw et al., 2011; Pillay-van Wyk, Bradshaw, Groenewald, & Laubscher, 2011; Joubert, Rao, Bradshaw, Vos, & Lopez, 2013; Groenewald et al., 2016; Matzopoulos, Groenewald, Abrahams, & Bradshaw, 2016; Prinsloo, Bradshaw, Joubert, Matzopoulos, & Groenewald, 2017). The literature review in Chapter 2 provides deeper insight into this.

As a result of South Africa's vital registration data not being optimal, National Burden of Disease studies have aimed to address data deficiencies through modelling of HIV/AIDS and other causes of death obtained from local empirical studies (Bradshaw et al., 2003; Bradshaw et al., 2004; Msemburi et al., 2016; Pillay-van Wyk et al., 2016a). Other national sources of injury data are South African Police Service (SAPS) and Road Traffic Management Corporation (RTMC) records. SAPS data were previously criticised for under-reporting (Bruce, 2010; Gould, Burger, & Newham, 2012), but can be used to monitor the SDGs to reduce the levels of violence, as they are the only available national source of homicide data. As the RTMC utilizes the SAPS accident report forms, these data can also be regarded as flawed and under-reported (Chokotho, Matzopoulos, & Myers, 2012a).

Efforts to address the dearth of representative injury mortality data in South Africa included injury mortality surveillance systems in Cape Town (Lerer, Matzopoulos, & Bradshaw, 1995; Lerer, Matzopoulos, & Phillips, 1997), which expanded to other cities in 2000, in various South African provinces as the National Injury Mortality Surveillance System (NIMSS) (Butchart et al., 2001). The NIMSS data were known to be urban-biased towards major metropolitan (metro) cities in South Africa, and there were some indications of differences in the leading causes of

injury for metro- and non-metro areas. Besides not being able to provide full coverage for all deaths at all state mortuaries in South Africa, due to logistical reasons and lack of funding, other challenges for the NIMSS included negotiations for access to post-mortem folders at mortuaries, and follow-up of missing information. The NIMSS accordingly proved unsustainable.

1.5 Data from forensic pathology mortuaries

Given the unsustainability of injury mortality surveillance nationally, and the unsuitability of the national vital registration system as a reliable source of injury deaths in South Africa, a national survey of mortality data was conducted at state forensic pathology mortuaries to collect cause-specific information and demographics on injury deaths for 2009 (Matzopoulos et al., 2015). The Injury Mortality Survey (IMS) data fills an important information gap in the South African literature, with representation of mortuaries in metro- and non-metro areas, to provide a reliable estimate of the national injury mortality profile. The IMS data will be used in the analysis of this thesis.

Given the high rate of injuries in South Africa, particularly arising from interpersonal violence, better quality data are required to improve prevention efforts and optimise the allocation of resources to high-risk groups. Hence, there is an urgent need to critically examine existing data sources, address the issue of data accuracy, and improve data collection efforts.

This study addressed the need to gain insight into urban-rural differences for injury deaths, and more specifically into the risk factors for homicide in this regard, in order to optimally target interventions. The terms metro/urban and non-metro/rural are used interchangeably throughout.

The literature review in Chapter 2 informed the Aims and Objectives in Chapter 3 of this thesis. Chapter 4 will discuss the methodology used in the analysis of data from the Injury Mortality Survey for this thesis. Chapter 5 will evaluate the quality of the IMS data, employing the framework of Rao et al (2005). Chapter 6 will report findings from the data in relation to a number of hypotheses concerning metro/non-metro injury mortality profiles and a number of explanatory variables. Chapter 7 will

conduct more focussed analysis concerning the role of explanatory variables including firearm use in relation to metro/non-metro differences in homicide mortality. In conclusion, Chapter 8 will summarize the main findings in relation to each objective, discuss the study's strengths and limitations and provide a set of recommendations pertaining to the main findings.

2 LITERATURE REVIEW

This literature review discusses in section 2.1 the global epidemiology of injuries, followed by South Africa's estimates for injury mortality. Section 2.2 considers how injury mortality statistics are recorded globally according to the International Classification of Diseases and Related Health Problems version 10 (ICD-10). Injury mortality differences in urban and rural areas, and risk factors for violence are discussed in sections 2.3 and 2.4 respectively. The dearth of representative injury mortality data in South Africa has been briefly addressed in Chapter 1. Section 2.5 describes a framework to evaluate data quality. Section 2.6 provides more detail on South Africa's fatal and non-fatal injury data sources, data quality concerns and the difficulty in sustaining some of these sources over the past two decades. Lastly, section 2.7 considers international initiatives for sustainable data collection.

Literature was sourced according to the topics listed above using search engines accessed via the University of Cape Town (UCT) Library's website and via the South African Medical Research Council (SAMRC) Library electronic resources (eResources). Relevant literature was also gleaned from reference lists of journal articles and the World Health Organization's (WHO) website. All sourced literature was added to an Endnote database (Endnote X7, 2013).

2.1 Overview of global and national estimates of injury mortality

2.1.1 Global estimates of injury mortality

Global estimates for injuries indicated that in 2013, more than 970 million people sustained injuries that warranted some type of healthcare (Haagsma et al., 2015), with 2015 estimates reporting 4.7 million injury deaths (Wang et al., 2016). Males aged 15-49 years account for the highest rates of disability adjusted life years lost (DALYs) due to injuries (Haagsma et al., 2015). Injuries account for 9% of all causes of death globally, ranging between 6% and 11% for high- to low-income countries respectively (WHO, 2017a). Global age-standardised death rates for injuries declined significantly, from 78.6 per 100 000 in 2005 to 66.2 per 100 000 in 2015 (Wang et al., 2016).

The highest injury-related mortality rate globally was for road traffic deaths at 18.8 per 100 000 population in 2015. This was followed by self-harm/suicide (11.5 per 100 000), falls (8.1 per 100 000) and interpersonal violence/homicide (5.5 per 100 000) (Wang et al., 2016). An estimated 1.2 million people die globally from road traffic injuries each year, with a further 50 million non-fatal road traffic injuries (Peden, 2004). In low- to middle-income countries violence-related deaths/homicide lead the injury profile. The 2015 global estimate for homicide was 6.4 per 100 000 population, and the highest rates were in the Americas (18.6 per 100 000) and Africa (10.3 per 100 000) (WHO, 2017b). The Africa region's estimates are based on homicide data from 13 middle-income and 14 low-income countries (WHO, 2014b), representing 70% of the region's population.

2.1.2 National estimates of mortality

In South Africa, injuries accounted for 9.6% (50 737 deaths) of all causes of death in 2012. Figure 1 indicates the contribution of injuries to the quadruple burden of disease, which also includes HIV/AIDS and tuberculosis (TB), communicable diseases (i.e. maternal causes, perinatal conditions and nutritional deficiencies), and non-communicable diseases (i.e. cardiovascular diseases, malignant neoplasms, chronic respiratory and digestive diseases, musculoskeletal and genitourinary conditions, mental health disorders and neurological conditions) (Msemburi et al., 2016). Injury deaths have a strong age-pattern between 15-44 years.

The 2009 Injury Mortality Survey data were used to estimate the injury cause profile within the estimate of the overall injury mortality rate derived by the 2nd National Burden of Disease (NBD) study (Pillay-Van Wyk et al., 2014; Msemburi et al., 2016; Pillay-van Wyk et al., 2016a) and extrapolated to 2012. The envelope of injuries by age and sex for the NBD study were derived by estimating the completeness of death registration and applying the proportion of injury deaths reported in Stats SA data. The GBD estimates could not be used to inform the NBD study, as their estimates were not derived below national level for South Africa. The data sources used for the GBD 2013 study for South Africa included the vital registration data from Stats SA for 1980-1982 and 1993-2010, Census 2001, 2006 and 2011, the 2007 Community Survey, the 1998 and 2003 Demographic Health Survey and household surveys from the 1990's (GBD 2013 Mortality and Causes of Death Collaborators, 2015).

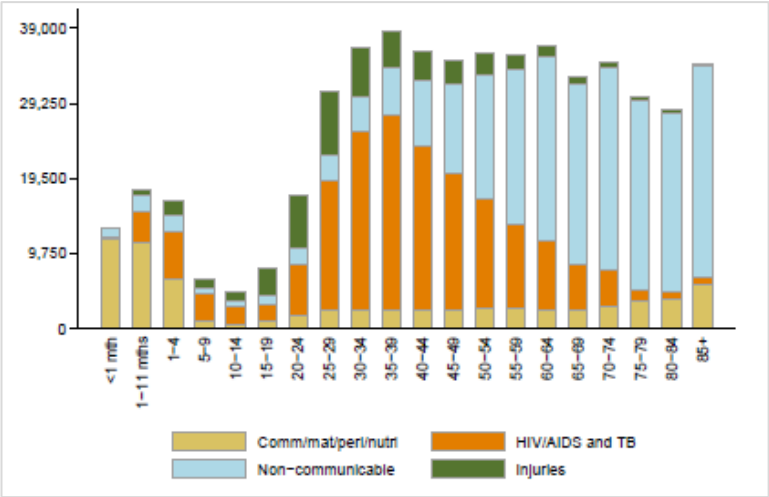

Figure 1. Deaths by broad cause and age, 2012 (N= 528 947)
Source: 2nd National Burden of Disease study, Msemburi et al. (2016)

The 2nd NBD study also indicated that the leading causes of injury death were interpersonal violence and road injuries, with an estimated age-standardised death rate of 35 per 100 000 population each, making them the eighth and ninth leading causes of death (Table 1) for South Africans in 2012, but the ranking was higher for males (Msemburi et al., 2016). The current NBD estimates show no difference between the rates of interpersonal violence and road injuries, while the ratio for interpersonal violence was 1.6 times higher than road traffic deaths nationally in 2000.

Table 1. Top-10 single causes of death, 2012 age-standardised rates (ASR) per 100 000

	Person ASR per 100 000		Male ASR per 100 000		Female ASR per 100 000	
1	HIV/AIDS	319	HIV/AIDS	353	HIV/AIDS	296
2	Cerebrovascular disease	110	Cerebrovascular disease	111	Cerebrovascular disease	108
3	Ischaemic heart disease	69	Ischaemic heart disease	94	Hypertensive heart disease	55
4	Lower respiratory infections	61	Tuberculosis	84	Ischaemic heart disease	52
5	Tuberculosis	55	Lower respiratory infections	78	Diabetes mellitus	52
6	Hypertensive heart disease	53	Interpersonal violence	61	Lower respiratory infections	50
7	Diabetes mellitus	51	Road injuries	53	Tuberculosis	33
8	Interpersonal violence	35	Diabetes mellitus	51	Diarrhoeal diseases	32
9	Road injuries	35	Hypertensive heart disease	49	Renal disease	29
10	Renal disease	34	COPD	47	Cervical cancer	19

Source: 2nd National Burden of Disease study, Msemburi et al. (2016)

This is due to the decline in South Africa's homicide rate, from 74 per 100 000 population in 1997 to 35 in 2012 (Msemburi et al., 2016). The 2016/2017 South African Police Service (SAPS) homicide rate of 34.1 per 100 000 population (SAPS, 2017b) indicates that it is still nearly six times the global rate for homicide (WHO, 2017b). The South African homicide rate was previously eight times higher than the global rate, which also declined over this period (WHO, 2002; Bradshaw et al., 2004). The homicide rate for South Africa is reported to be higher in metro areas in comparison to non-metro areas (Matzopoulos et al., 2015).

South Africa's road traffic injury mortality rate has been fairly constant from 1997 to 2012 and, at 34.7 per 100 000 population (Msemburi et al., 2016), was similar to the country's homicide rate. The road traffic injury mortality rate for South Africa was double the global average in 2000 (Norman et al., 2007) and in comparison to the latest global road traffic injury mortality rate of 18.8 per 100 000 population has not changed substantially. National estimates for suicide and other unintentional injury mortality rates were nearly three times lower than those for homicide and road traffic injury deaths.

2.2 How are mortality statistics recorded?

Mortality-related indices in the form of death counts, death rates, leading causes of death and years of life lost, among others (Segui-Gomez & MacKenzie, 2003) are commonly derived from country-specific vital registration data, which documents births and deaths within a population. In the event of death, a death certificate is completed and specific information on the immediate and underlying cause of death is captured within the vital registration system. While this seems a straightforward process and is usually a requirement by law, only high-income countries and some middle-income countries record these statistics accurately (WHO, 2010a). The benefit of a vital registration system is that the cause of death recorded by a pathologist in a death certificate is captured in a central database, and provides information by age and sex. However, the limitations include limited information on the injury event prior to death and there is the possibility of erroneous ICD-10 coding (Segui-Gomez & Hyder, 2011). ICD-10 (WHO, 2016a) is used to classify causes of death and is most commonly referred to when recording mortality-related indices. Table 2 lists the causes of injury death and the corresponding ICD-10 codes:

Table 2. Injury-related mortality and corresponding ICD-10 codes (WHO, 2016a)

Cause of injury	ICD-10 code
Homicide	X85-X99, Y00-Y09
Suicide	X60-X84
Transport injuries	V00-V99
Road traffic injuries	V00-V04,V06, V09, V80, V82-V85, V87, V89
Other transport injuries	V05, V81, V86, V88, V90 -V99
Poisonings (including herbal)	X40-X49, Y67
Falls	W00-W19
Fires, heat and hot substances	X00-X19
Drowning	V90, V92, W65-W70, W73, W74
Mining accidents	W77, Y37
Other threats to breathing	W75-W76, W78-W84
Mechanical forces	W24-W34, W45-W46
Exposure to natural forces	X30-X39
Adverse effects of medical and surgical treatment	Y39-Y66, Y68-Y84, Y88
Animal contact	W53-W59, X20-X27, X29
Other unintentional injuries	W20-W23, W35-W44, W49-W52, W60, W64, W85-W94, W99, X28, X50-X58, Y38

Source: Matzopoulos et al. (2015)

In addition to vital registration data, mortality-related indices can also be derived from forensic pathology post-mortem reports, medical and police reports, motor vehicle crash reports and verbal autopsy interviews with family of the deceased (Segui-Gomez & Hyder, 2011). In certain low- and middle-income countries, forensic pathologist post-mortem reports can vary in quality and are often not easily accessible, unless population-based surveys are initiated (WHO, 2010a). In countries with no vital registration system, verbal autopsy interviews can be used to estimate cause-specific mortality at the community or population level. Interviews are held with caregivers or family members of the deceased, using a standardised questionnaire to elicit information on the medical history, signs, symptoms and preceding events to determine the cause of death (WHO, 2012a). The information recorded is subject to recall-bias and misinterpretation of the cause of death by family members interviewed. Police reports can provide more detail on the circumstances surrounding the injury death but this is subject to the completion of investigations and the final court outcome. Police data are not always considered complete, as they record only reported events

leading to under-counting (Bruce, 2010; Gould et al., 2012). South Africa's injury mortality data sources will be discussed later in this chapter.

2.3 Injury mortality differences in urban- and rural areas

Myers et al. (2013) conducted a study of injury deaths in the United States from 1999-2006 across 3 141 counties classified as urban and rural. The data were extracted from the National Vital Statistics System of the National Centre for Health Statistics, which captured these deaths according to ICD-10 codes from registered death certificates. This yielded 1 295 919 injury deaths during the time period. The overall injury mortality rate was 56.2 per 100 000 population, with unintentional injury highest (37.5 per 100 000 population) as a result of the high rate of motor vehicle-related deaths (14.9 per 100 000). Firearms had the second highest rate for injury mechanisms (10.4 per 100 000) but these were not distinguished by intent. Homicide and suicide were classified as intentional deaths, with a combined rate of 17 per 100 000. The injury mortality rate was 1.5 times higher in rural counties (73.8 per 100 000) in comparison to urban counties (49.7 per 100 000). After adjusting for year of death, median income, county region, percentage of adults living alone, males, race and ethnicity, college education and unemployment, the relative risk of injury death was 1.2 times higher in the most rural counties compared with the most urban, as classified according to an urban rural continuum, which distinguished counties by population size and proximity to metropolitan areas.

A study in New South Wales (NSW), Australia utilised mortality data from the Australian Bureau of Statistics from 2000 to 2004 (Mitchell & Chong, 2010). This information is drawn from death certificates certified by a medical practitioner or forensic pathologist, and contains demographic data and cause-of-death statistics coded to ICD-10. The 11 577 injury-related deaths recorded during this period provides an overall rate of 34.2 per 100 000 population, with the rate for rural residents (48.1 per 100 000 population) nearly 1.5 times higher than that for urban residents (33.2 per 100 000 population). This difference seems to be driven by both males and females in rural areas, where rates were 1.5 and 1.3 times higher than their urban counterparts respectively. Deaths that involved machinery, firearms and being struck by/against objects were three to four times more likely in rural than urban areas, while motor vehicle crashes were twice as likely in rural areas. Deaths that were as a result

of machinery were attributed to tractor rollovers and run overs. The likely reasons for the difference between rural and urban deaths due to firearms were not discussed, including what proportion of these deaths were as a result of violence.

Yang, Zhou, Huang, and Wang (2004) also reported higher injury mortality rates for rural residents of China in comparison to urban residents, using 10 years (1991-2000) of national Disease Surveillance Points (DSP) data classified according to ICD-10. The average annual age-adjusted death rate for rural residents (74.6 per 100 000) was nearly double the rate for urban residents (38.7 per 100 000). Another study in Hubei Province, China (Liu et al., 2012), which also utilised DSP data from 2006-2008, also reported significantly higher average annual age-adjusted injury death rates for rural residents (70.7 per 100 000) in comparison to urban residents (30.1 per 100 000). The highest injury mortality rate was for suicide, which was significantly higher in rural areas and particularly high among the elderly. In addition, mortality rates for traffic-related injuries, drowning and crushing were significantly higher in rural areas. The leading injury mortality rates in urban areas were traffic-related injuries, followed by falls and suicide. The rates for males and females in rural areas were nearly double those in urban areas.

In a study in northern Finland, (Raatiniemi et al., 2016) reported on injury mortality differences in urban and rural areas over a five-year period from 2007-2011. Finland had the fourth highest injury mortality rate (64 per 100 000) in the European Union between 2008-2010 (EuroSafe, 2013). Raatiniemi et al. (2016) utilised data coded according to ICD-10 from the Finnish cause-of-death registry. Rural injury mortality rates (65 per 100 000) were higher than those in urban areas (45 per 100 000). General level falls -classified as low-energy trauma by the authors, suicide and traffic incidents were the leading causes of death. No significant differences were found in the rates of low-energy trauma, suicide or assault between urban and rural areas.

In a study assessing urban-rural mortality differences in England and Wales in 2004, Gartner, Farewell, Dunstan, and Gordon (2008) found that after adjusting for deprivation, the other unintentional injury death rate was significantly higher in rural areas for males and females in England and males in Wales. This was mostly as a result

of road traffic incidents. The suicide rate for males in England was significantly higher in rural areas compared to urban after adjusting for deprivation.

These studies show that rural injury mortality rates tend to be higher than urban rates in high-income countries –where these data are available. The urban-rural difference persists, even after adjusting for demographic and socio-economic differences. The countries – from different continents, had very different profiles of injury mortality, with not one having homicide as the leading cause of injury death. Transport-related deaths appear to have played a leading role in the injury mortality profile of some of these countries, with deaths reported as highest in rural areas. Reasons for this have been cited as the greater distances to travel on rural roads and the higher speed limit on national roads, which impacts on the severity of crashes. The response time of emergency vehicles and not having specialist practitioners readily available in rural areas can also cause a higher risk of fatalities (Maio, Green, Becker, Burney, & Compton, 1992; Weiss, Ellis, Ernst, Land, & Garza, 2001; Clark, 2003; Peek-Asa, Zwerling, & Stallones, 2004). Behavioural factors such as exceeding the speed limit, not wearing seatbelts and exceeding the legal alcohol consumption limit for drivers also lead to a higher risk of transport-related deaths (Peek-Asa et al., 2004; Zwerling et al., 2005). This applies to urban and rural areas for high- and middle-income countries.

There are some references to urban and rural areas in the published injury mortality literature for middle-income countries in Latin America, which tends to discuss this in the context of homicide. In Brazil in 2007, the leading cause of injury mortality was homicide followed closely by transport-related deaths (26.8 and 23.5 per 100 000 respectively). The lowest homicide rates were in the most heavily populated and developed regions of the south and south east, but the highest rates were in the larger cities (Reichenheim et al., 2011). More than 80% of residents in Brazil live in urban areas (Instituto Brasileiro de Geografia e Estatística, undated). Intense urbanisation since the beginning of the 1990s, decreased capacity of law enforcement agencies, social disorganisation, and the possession of illegal weapons, drugs and alcohol are thought to have caused the higher rates in the cities (Reichenheim et al., 2011).

Briceño-León, Villaveces, and Concha-Eastman (2008) reviewed public databases of homicide for Latin-American countries and found that homicide rates (27.7 per 100 000) were considerably higher than suicide rates (6.3 per 100 000) for the region. Countries with the highest rates of homicide (Colombia, El Salvador, Venezuela and Honduras) were those with a high proportion of urban population and high rates of poverty. Countries with the lowest rates of homicide (Uruguay, Costa Rica and Chile) were highly urbanised with less poverty.

A review of the literature revealed no urban-rural nationally-representative studies on injuries for South Africa. This gap in the literature will be addressed in this thesis.

2.4 Risk factors for road traffic injuries

Haddon (1968) initially produced a matrix that illustrates the three factors: human, vehicle and environment, during the pre-crash, crash and post-crash event (Figure 2), with each of the nine factors allowing an opportunity for intervention to prevent a road traffic crash.

		FACTORS		
PHASE		HUMAN	VEHICLES AND EQUIPMENT	ENVIRONMENT
Pre-crash	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash-protective design	Crash-protective roadside objects
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Figure 2. Haddon's Matrix (Haddon, 1968)
Source: Peden (2004)

Haddon's work was enhanced by using a "systems" approach to identify and correct major errors or design weakness that contribute to road traffic crashes, as well as to alleviate the severity and consequences of injury by:

-reducing risk exposure

-preventing the occurrence of road traffic crashes

-reducing the severity of an injury during a crash

-reducing the consequences of injury by improving post-crash care

This integrated approach to road safety produced a substantial decline in road deaths and serious injuries in highly motorized countries (CDC, 1999; Lonero et al., 2002). The practicalities of such a systems approach: by reducing speed in urban areas, providing pavements/sidewalks, design modifications to car and bus fronts to protect pedestrians, and a crash-protective interface between road infrastructure and vehicles among others remain a challenge for road safety policy-makers (Peden, 2004).

2.5 Risk factors for violence

As the leading cause of injury death in South Africa, there is a focus on homicide in this thesis as outlined in a later chapter. The risk factors for violence are discussed in the following section, utilising the WHO ecological model (Figure 3) as a framework to understand the interaction of the many influences on violence (WHO, 2002).

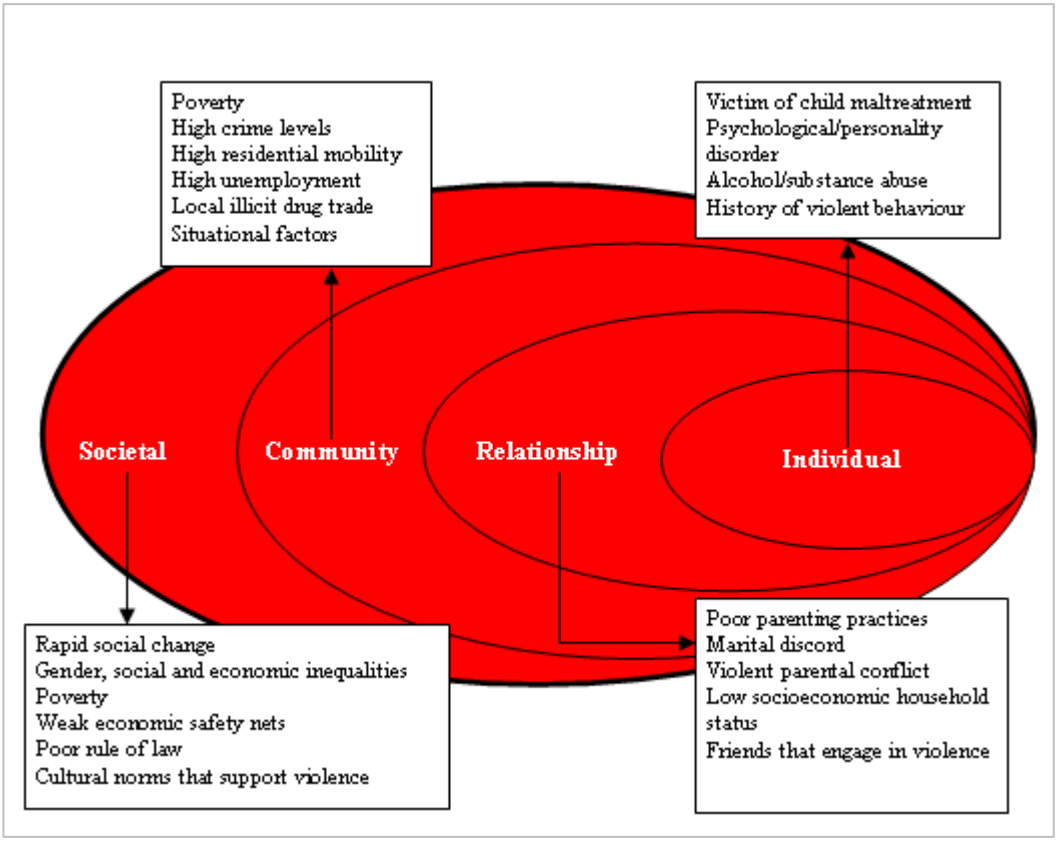

Figure 3. The ecological framework: examples of risk factors at each level
Source: WHO Violence Prevention Alliance (2018)

The model examines the factors that influence the risk of perpetrating, or being a victim of, violence by considering four levels:

Individual-level factors: These include demographic characteristics (age, sex, education, income), substance abuse and a history of aggressive behaviour or suffering abuse.

Relationship factors: Considers close relationships with family, friends, intimate partners and peers; and, explores how these could increase the risk of being a victim or perpetrator of violence.
Community factors: Seeks to identify the characteristics of community settings such as schools, workplaces and neighbourhoods that increase the risk for violence. At this level, risk could be influenced by residential mobility, population density, high unemployment or the local drug trade.
Societal factors: At this level violence or the inhibition thereof depends on the availability of weapons as well as social and cultural norms. These include giving priority to parental rights over child welfare and norms that entrench male dominance over women and children amongst others. Broader societal factors include policies that help to sustain economic and social inequality between groups in society.

When applying the ecological model as a framework for understanding violence in the South African setting, the *individual-level factors* to consider include the fact that male homicide rates are approximately six times higher than female homicide rates (Matzopoulos et al., 2015). Males are therefore at greater risk. This is higher than the global average, where the male homicide rate is four times higher than females, but is lower than that in other middle-income countries such as Brazil and Colombia, where the male to female homicide rate ratio was 11:1 (WHO, 2014b). Interpersonal violence was the sixth leading cause of death for South African males in 2012 but did not feature in the 10 leading causes of death for females. Interpersonal violence accounted for a high proportion of premature mortality and was the second leading cause of years of life lost for males (Msemburi et al., 2016). The victims are mostly adolescents and young adults (15-44 years) (Norman et al., 2007; Matzopoulos et al., 2018).

As for race as a risk factor for violence, there has never been a fully representative national source for data on race and homicide in South Africa leaving uncertainty as to the true magnitude of risk among the South African population. Analysis based upon Stats SA data and mortuary data claimed that the Coloured homicide rates historically outweighed those of other race groups and continued to do so until the early 2000s (Leggett, 2004a; Leggett, 2004b; Thomson, 2004). This conclusion, firstly, did not take into account, that historically only 50% of deaths for Blacks in the 1980s were recorded by vital registration data, and deaths in the Black

homelands were excluded (Dorrington, Bradshaw, & Wegner, 1999). Secondly, it did not take into account that the Coloured population was overrepresented in mortuary data used in the early 2000s (Butchart, 2000; Butchart et al., 2001). A separate analysis (Prinsloo, Bradshaw, & Laubscher, 2010) of this historical vital registration data compared the homicide to suicide ratio for urban Blacks (as no data were available from the homelands) and Coloureds for 1980-1989, and found between 12 and 18 homicides for every suicide. The authors concluded that Coloured homicide in the 1980s was high, but comparable to the homicide rates for the available urban Black population at that time. A later analysis of mortuary data from 2001-2005 for five South African cities found that the risk for homicide among Blacks was significantly higher than Coloureds (Matzopoulos, 2012).

Certain mental and behavioural factors also act as enablers of violence. More than 40% of Grade 8-10 learners in a Western Cape school survey (Morojele et al., 2013) were reported to be at medium risk and nearly 15% at high risk for mental health problems. Nearly two-thirds were classified as medium risk for aggressive behaviour, while 6.9% were considered to be in the high-risk category. The prevalence of having experienced delinquent-type behaviours like theft, property damage and bullying were significantly higher in male compared to female learners. Other risk factors included threats by gang members and offers of drugs by individuals in the community. Sixty six per cent of learners reported having ever used alcohol, followed by 47% having ever used tobacco, nearly a quarter reported cannabis use and 2% reported having used methamphetamine.

When considering *relationship factors*, men witnessing abuse of their mothers during childhood is associated with perpetrating violence as adults. This includes intimate partner violence, engaging in violence at work and within the community, being arrested for violent actions and antisocial behaviour, and being arrested for possession of an illegal firearm (Abrahams & Jewkes, 2005). Not all children are similarly affected though and the effects of witnessing abuse will depend on the child's sex and age, whether the child was also physically abused, the time since the exposure to violence and the child's relationship with adults in the home (WHO/London School of Hygiene and Tropical Medicine, 2010). A South African school study found that 42.2% of young people interviewed had experienced some form of maltreatment,

whether physical, sexual, emotional or neglect, at some point in their lives. Sexual abuse was strongly associated with mental health problems, as victims were twice as likely to report anxiety and depression, and three times as likely to report symptoms of post-traumatic stress disorder, as other young individuals. Victims were also likely to have problems with school work and school attendance (Artz et al., 2016).

Relationships filled with conflict about finances and jealousy and women's transgression of conservative gender roles put women more at risk of violence (Jewkes, 2002). Both men and women are affected by intimate partner violence, but women tend to be more susceptible (Krug et al., 2002). Estimates indicate that 38% of female homicides globally were committed by male partners, while 6% of males were killed by their female partners (WHO Department of Reproductive Health and Research, London School of Hygiene and Tropical Medicine, & South African Medical Research Council, 2013). Although South Africa's female homicide rate reduced significantly from 24.7 to 12.9 per 100 000 between 1999 and 2009, the rate of intimate femicide decreased non-significantly from 8.8 to 5.6 per 100 000. There was no difference in the rate of suspected rape homicide between 1999 and 2009 but there was a significant reduction in the rate of female firearm homicide (Abrahams et al., 2013). This was attributed to the implementation of stricter gun control through the Firearms Control Act No. 60 of 2000, which was fully effective from 2004 (Firearms Control Act, 2004).

Community factors can greatly influence the risk of violence. Police statistics indicate that seven of the ten leading police station areas for homicide were predominantly in low socio-economic settings in the Western Cape and the remainder in KwaZulu-Natal (KZN) and the Eastern Cape (SAPS, 2016a). The rate of violence for the Western Cape is influenced by migration of individuals from rural to urban areas, in search of employment in the city (SAPS, 2017a). Being employed, having a high-risk job and commuting to- and from work in low socio-economic settings have been significantly associated with an increased risk of violence, as individuals are targeted for money (Doolan, Ehrlich, & Myer, 2007).

A national school violence study (Burton, 2008) showed that 15.3% of learners experienced threats of violence, assaults, sexual assault and robbery at school over a

12-month period. In less than 2% of instances, gang members from communities and other schools entered the school premises to commit acts of violence. Learners also had easy access to alcohol, drugs and weapons within their schools and immediate communities. The study showed a strong association between the home environment and violence at school, with one in ten primary school learners reporting parental use of illegal drugs, that their caregiver or parent had been in jail, and one in five secondary school learners reported that one of their siblings had been in jail. Violent incidents at school are thought likely to lead to increased truancy and school dropout rates, poor academic performance levels and low self-confidence among victims, subjecting affected individuals to vulnerability to violence later in life. A study of Grade 10 high-school learners in KwaZulu-Natal municipalities (Khuzwayo, Taylor, & Connolly, 2016) found that 23.9% were bullied, 21.7% missed school for fear of their safety, 15.4% were involved in physical fights and 2.4% reported carrying weapons to school. The study reported a significant association between being involved in a physical fight and missing school; and that male learners were more likely to carry weapons than female learners.

Some of the *societal factors* that influence the risk of violence were addressed by the relationship and community factors affecting violence. Probst, Parry, Wittchen, and Rehm (2018) reported that in South Africa in 2015, an estimated 62 300 adults died from alcohol-attributable causes. The majority (60%) of these deaths occurred in the lower socio-economic status (SES) group. Injury deaths accounted for approximately 12 300 deaths but had similar numbers of deaths in the low and middle SES groups, with a lower number of deaths in the high SES group. Alcohol-attributable injury deaths therefore affects a broader socio-economic group that should be targeted for brief interventions and for the implementation of other policies against the use of alcohol. In South Africa, Parry, Harker-Burnhams, and London (2012) provided the public health case for banning alcohol advertising supplemented with other alcohol-harm related policies and brief interventions for problem-drinkers, citing global evidence that alcohol advertising influences young people's behaviour and not only influences brand choice as claimed by the alcohol industry. In 2013, the South African Cabinet approved a Bill to ban alcohol advertising, but this was met with strong opposition from the liquor industry, which claims it will have dire consequences

for the economy, causing delays in its implementation (Parry, London, & Myers, 2014).

The effect of poverty and inequality has been demonstrated by national South African Police statistics for homicide, which was more prevalent in low socio-economic settings in the Western Cape (SAPS, 2016a, 2017a). A validation of the police homicide trend data confirmed a decline in homicide rates from 2004 to 2011, after which rates started to increase, particularly for the Western Cape (Prinsloo, Matzopoulos, Laubscher, Myers, & Bradshaw, 2016). The earlier decline in homicide rates coincided with the implementation of the Firearms Control Act (FCA) No. 60 of 2000 (Firearms Control Act, 2004), which enforces stricter criteria for firearm licensing and regulation including , removal of illegal firearms from circulation. A 5-city study of homicide in South Africa also found an association between a decline in firearm availability and a decline in firearm homicide rates (Matzopoulos et al., 2014).

However, an analysis of post-mortem data for Cape Town in the Western Cape found a 21% annual increase in firearm homicide between 2011 and 2013. The rate of increase for Coloureds was significantly higher in comparison to other race groups (Matzopoulos et al., 2018). An ex police officer who was arrested for supplying illegal weapons to gangs in Western Cape communities during this period, was later convicted and sentenced to 18 years in prison (Dolley, 2014; Baadjies, 2015; Petersen, 2016).

To date, these illegal firearms have been linked through police ballistics to 1 066 murders and 1 403 attempted murders between 2010 and 2016 (Thamm, 2016; Gun Free South Africa, 2017). The available firearm homicide data for Cape Town indicated that there were 2 701 firearm homicides (37.3% of 7 237 homicides) between 2010 and 2013 (Matzopoulos et al., 2018). Assuming the 2010 to 2013 average of 675 firearm homicides per year (a conservative estimate based on the fact that the numbers showed an increasing trend), will add another 2 025 firearm homicides for 2014 to 2016. Based on this assumption, the 1 066 firearm-related homicides that were linked to illegal firearms, accounted for more than one-fifth (22.6%) of the estimated 4 726 firearm homicides between 2010 and 2016. These deaths included at least 261 child victims of which 89 died (Thamm, 2016; Gun Free South Africa, 2017). Most children

growing up in low- to middle-income communities have very little social protection – a term that refers to a safety net during economic uncertainty. A safety net could include social protection for old age, incapacity, unemployment, housing, family (presumably in the form of child grants) as barriers to forces of social disorganisation. Nations with high levels of social protection have lower homicide rates; and the strength of the association between poverty and homicide is found to be weaker for these nations (Rogers & Pridemore, 2013).

Eisner (2015) discussed the fact that homicide has been declining globally, but has increased in parts of Central and South America and the Caribbean. The three most important factors that drive changing homicide levels over time, according to the author are urbanisation, change in income inequality and economic growth. Latin America and the Caribbean are reported to be the most urbanised regions globally, with 80% of people living in cities. This region is home to 47 of the 50 most dangerous cities worldwide. According to Krisch, Eisner, Mikton, and Butchart (2015), 50% of the world's population are living in cities and this could increase to an estimated 75% by 2050. Eisner (2015) states that the evidence for factors driving homicide levels is rather ambiguous, as some of the most urbanised countries such as Singapore, Hong Kong, Japan, Switzerland and The Netherlands have much lower homicide rates. However, these countries have the financial resources to make them more resilient to coping with population density, unemployment and crime.

There appears to be a geographical concentration of homicide in the Western Cape that is different to other large metropolitan areas. Analysis of the leading SAPS precincts for homicide for the four large metro-area provinces in 2010 revealed that 22% to 25% of homicides in the Eastern Cape, Gauteng and KwaZulu-Natal (Crime Stats SA, 2015a, 2015b, 2015c) occurred within only ten police precinct areas. In the Western Cape however, homicide tends to be more concentrated in certain suburbs, as the ten leading police precinct areas accounted for between 43% and 48% of homicide in 2010 (Crime Stats SA, 2015d) and 2016 (Crime Stats SA, 2015e) respectively. This could be an indication of gang violence, as most of the leading suburbs associated with multiple murders during one incident were from the Western Cape (SAPS, 2016a).

The geographical concentration of homicide is not only a South African phenomenon. Globally, nearly half of all homicide occurred in only 23 countries that account for 10% of the global population (United Nations Office on Drugs and Crime, 2011; Eisner & Nivette, 2012; Eisner, 2015). This is not only limited to low- and middle-income countries (Eisner, 2015), but was also reported for cities in the United States (Muggah, 2014; Krisch et al., 2015).

de Boer, Muggah, and Patel (2016) suggested seven factors that shape city resilience: greater income and social equality; effective policing and judicial systems; micro-economic security and social protection; the provision of basic services and infrastructure; social cohesion; social networks and support; and, strong community to government and inter-governmental cooperation. Pinker (2011, 2012) discussed the reasons for the decline in violence, which he states, was much higher in pre-state times, and during the middle-ages when slavery was allowed and when mutilation and torture were common as criminal punishments. He also argued that there has been a decline in wars and genocide and a decline in ethnic riots, and believes that we are living in a globally much more peaceful society today. He believes that violence declined because the change in technology and economic efficiency made life more pleasant and allowed humans to place a higher value on life in general. The trading of goods and services also enabled people to consider one another as more valuable for mutual benefit, and resulted in, individuals developing a sense of empathy and using logic to avoid being tempted into committing violence. He also discussed the great reduction in crime in the 1990s and the policy shift in the United States, towards getting tough on crime measures such as mandatory minimum sentences, raising incarceration rates and increasing the size and public visibility of police forces.

Besides the direct physical injuries of violence, the preceding individual, relationship, community and societal risk factors for violence impact on the mental and general health of those affected. A South African Comparative Risk Assessment study identified interpersonal violence (including the injury burden and the long-term mental and behavioural consequences) as the second leading cause of healthy years of life lost, after unsafe sex. The related health outcomes for intimate partner violence included major depression, anxiety disorders, alcohol and drug use disorders, HIV/AIDS, self-inflicted injuries, physical disability and femicides among others.

This indicates that interpersonal violence is an important public health problem that warrants significant policy interventions that address the risk factors for violence (Norman et al., 2010).

2.6 Assessment of data quality

Prior to discussing South Africa's available injury mortality data sources, this section reflects on evaluating the quality of mortality data. Quality assurance is an ongoing process, which usually starts during the preparation and sampling of a survey, continues with data collection and analysis, to writing up the report (Üstun, Chatterji, Mechbal, & Murray, undated). To ensure accurate and reliable results for publication, certain quality assurance procedures should be in place. Quality can also be assessed after publication of the study results through a systematic review of the literature for a particular topic. For systematic reviews, there are known and well-established frameworks in place (Higgins & Green, 2011; Hoy et al., 2012). There are various dimensions and indicators of data quality to consider in public health surveillance systems, health surveys and vital registration systems. For public health surveillance systems, the United States' Centers for Disease Control and Prevention (CDC) have produced guidelines on system attributes to consider when evaluating the performance of an ongoing surveillance system (CDC, 2001).

Rao et al. (2005) developed a conceptual framework to evaluate national cause-of-death statistics in China. This was based on four attributes: *generalisability, reliability, validity* and *policy relevance*. Since mortality data collected via a retrospective survey of mortuary reports will be used in this thesis, this framework will be utilised, as outlined in Chapter 5, to evaluate the quality of the data.

The first attribute in this framework of Rao et al. (2005) is *generalisability*, which refers to how representative the statistics are with respect to the population and is assessed using two criteria:

- *Coverage*: refers to the proportion of the population covered by the data, whether urban/rural, the geographical sectors and socio-economic groups. It is also relevant in sample-based systems.
- *Completeness*: the percentage of deaths with a registered cause, within the population covered.

The second attribute, *reliability* refers to consistency of the data with respect to epidemiological expectations. The criteria proposed to assess this include:

- *Consistency* of *cause patterns* with general levels of mortality.
- *Consistency* of cause-specific *mortality rates* over time.

The *validity* of the data is considered as one of the most important attributes to assess within the framework and three criteria are proposed:

- *Content validity*: refers to the periodic comparison of the data with alternative sources or a known 'gold standard'.
- *Use of ill-defined categories and codes*: the proportion of deaths that are ill-defined or poorly diagnosed.
- *Incorrect or improbable age or sex dependency*: certain causes of death are age-dependent and, in the case of natural deaths, sex-specific.

To complete the framework, the *policy relevance* of the data is assessed using two criteria:

- *Timeliness*: outdated cause-of-death data can rapidly lose their relevance for formulating programmes and policies.
- *Geographical disaggregation*: Population-based health statistics are essential to informing health-related policies and targeting interventions.

The evaluation framework formulated by Rao et al. (2005) was also applied to a study evaluating cause-of-death statistics from the Mortality Information System in Brazil (França, de Abreu, Rao, & Lopez, 2008) and to evaluate the quality of national mortality statistics from civil registration in South Africa (Joubert et al., 2013).

The quality of cause-of-death data from the 2003 WHO mortality database was assessed by Mathers, Fat, Inoue, Rao, and Lopez (2005), after which Bhalla et al. (2010) assessed the availability, completeness and quality of global mortality data reported to the WHO mortality database for 2009. Death registration data were available for 83 WHO member countries, representing 28% of the global population. Completeness of death registration was determined by crudely comparing with projected mortality reported by the United Nations. Completeness was deemed high when it was more than 80% of the expected value, medium between 60% and 80% and low for the remainder. Completeness was high (>80%) in 62 of the 83 countries analysed and South Africa's completeness of vital registration for 2005 was considered

medium (60-80% complete). In an assessment of the quality of death registration data, 18 countries classified more than 20% of injury deaths as undetermined intent or manner. This included Singapore as the only high-income country. Of the 18 countries listed, South Africa had the third-highest proportion (66%) of undetermined injury deaths in the 2005 vital registration data. Overall, only 20 out of 83 countries could provide reliable estimates for all causes of injury death, while 47 countries were considered to have reliable estimates of road injury deaths and 60 countries had reliable estimates of suicide or homicide, but South Africa was not one of them (Bhalla et al., 2010). The reasons for the high proportion of undetermined deaths and misclassification of injury deaths in the vital registration system are discussed in the next section.

2.7 Injury data sources in South Africa

2.7.1 South African data sources for fatal injuries

South Africa's births and deaths are recorded through the country's vital registration system, by Stats SA. As discussed, the coverage and completeness of this system have not been optimal and there have been initiatives to gain institutional lessons from Australia, Sweden and the United States, which brought about much improvement between 1997 and 2002 (Bah, 2009). By 2007 coverage of death registration was estimated at 82 per cent (Bradshaw et al., 2011), but misclassification of deaths continued (Bradshaw et al., 2011; Pillay-van Wyk et al., 2011; Joubert et al., 2013; Groenewald et al., 2016; Matzopoulos et al., 2016; Prinsloo et al., 2017).

The misclassification of deaths are caused by Stats SA applying the international coding regimen where undetermined deaths of unspecified intent, usually coded to ICD-10 code Y34 (unspecified event, undetermined intent) are defaulted to ICD-10 code X59 (accidental exposure to unspecified factor) (Stats SA, 2009). These deaths of undetermined intent stem from the Inquest Act of 1959 (Inquests Act 58, 1959), which prohibits forensic pathology officers from declaring the manner of non-natural death on the death certificate, as it may prejudice the inquest's findings. In many instances, the pathologist would only report the death as non-natural with a penetrating wound for instance, instead of stating that it was a homicide by sharp object or perhaps even a gunshot wound. As a result, South Africa's vital registration reported in 2009 that 63% of non-natural deaths were the result of other unintentional injuries (Stats

SA, 2011). This large percentage of unintentional injury deaths is unlikely in the South African context, as the majority of injury deaths are as a result of violence and road traffic injuries (Norman et al., 2007). The default ICD-10 code X59 (accidental exposure to unspecified factor) appears to be used by at least 15 countries -more than half in Western Europe, for more than 20% of other unintentional injury deaths, instead of specifying the specific ICD-10 code for other unintentional injuries. A similar proportion for broad cause categories of unspecified unintentional road injuries (ICD-10 codes: V89, Y85.0) were reported for 40 countries and the mechanism of homicide was not specified for more than 20% of homicides in 13 countries (Bhalla et al., 2010).

The latest evaluation of vital registration data by Joubert et al. (2013), utilising Rao et al's. (2005) framework, indicated that the coverage and completeness of death registration exceeded 90% and were rated satisfactory, as were temporal consistency, age/sex classification, timeliness and sub-national availability of the data. Epidemiological consistency could not be adequately assessed, as the regression models used to predict cause-specific compositional mortality by broad-cause groups (Salomon & Murray, 2002) could not take the high proportion of HIV/AIDS deaths seen in South Africa into consideration. Ill-defined causes and content validity were rated unsatisfactory. The impact on content validity in the event of undetermined deaths (ICD-10 code Y34) defaulting to other unintentional injuries will be discussed in Chapter 5.

The Africa Centre Demographic Health and Information System (ACDIS) records births, deaths, marriages, and migration of household members via household visits in a district in northern KwaZulu-Natal. Information on deaths are recorded via verbal autopsy (Otieno, Marinda, Bärnighausen, & Tanser, 2015). While a verbal autopsy is a useful instrument for the collection of injury data, the challenge is that it is restricted to a limited population.

During the mid-1990s, a mortuary-based surveillance system was piloted for the Cape Metropole (Lerer et al., 1995; Cape Town Non-natural Mortality Study Group and Health Consulting Office, 1996; Lerer et al., 1997). This was expanded to address the dearth of reliable injury mortality statistics in South Africa. The National Injury Mortality Surveillance System (NIMSS) was established in 1999 through initial

funding from the Department of Arts, Culture, Science and Technology and recorded non-natural deaths from ten urban area mortuaries (Butchart, 2000; Butchart et al., 2001). This was a collaboration between the Technology and Business Development's Health Consulting Office at the South African Medical Research Council (SAMRC) and the Institute for Social and Health Sciences at the University of South Africa (UNISA). Collaborators from these units merged in 2001 to form the SAMRC-UNISA Crime, Violence and Injury Lead Programme and continued the expansion of the NIMSS. By 2004, the NIMSS coverage expanded to 35 mortuaries in seven out of nine provinces, of which Mpumalanga was the only rural representation (Matzopoulos, 2005). Between four and five cities in seven provinces had full representation of all mortuaries within a city for 2004 and 2005, which enabled the calculation of age-standardised rates (Matzopoulos, 2005; Prinsloo, 2007). The utility of this data was demonstrated in an analysis of firearm- and non-firearm homicide data for five cities, namely Cape Town, Durban, Johannesburg, Port Elizabeth and Pretoria, to assess the impact of the Firearms Control Act (Firearms Control Act, 2004) on firearm homicide rates from 2001-2005 (Matzopoulos et al., 2014).

No NIMSS report was published for 2006, as the overseeing NIMSS manager at that time decided to only publish a report for 2007 (Donson, 2008). For 2008, the NIMSS had full coverage for the Western Cape's 18 mortuaries through the separate initiation of an electronically captured Provincial Injury Mortality Surveillance System (PIMSS) by the Provincial Government Health Department's Burden of Disease Reduction Project (Bourne et al., 2007; Matzopoulos et al., 2011). While this enabled the NIMSS to cover 62 mortuaries in eight provinces, a number of key urban-area mortuaries in Pretoria and Durban were not captured (Donson, 2009). By 2009, the Western Cape mortuaries were excluded from the NIMSS, as no agreement could be reached between the SAMRC-UNISA Crime, Violence and Injury Lead Programme and the Western Cape Department of Health regarding ownership of the PIMSS data (Matzopoulos, 2012). Subsequently, the PIMSS ended its collaboration with the NIMSS, but continued surveillance of cause-of-death information in the Western Cape (Western Cape Government, 2015).

The latest reports produced by the NIMSS represent just Gauteng (excluding Pretoria as the Forensic Pathology Services denied access to the post-mortem folders)

and Mpumalanga (MRC-UNISA Safety and Peace Promotion Research Unit, 2012). Without improving its coverage, the NIMSS can no longer be considered a national injury mortality surveillance system. The fluctuating coverage of the NIMSS and lack of consistent, reliable information on injury mortality causes a substantial gap in up-to-date statistics on injury mortality at a national level. Other independent national sources of data relate to studies on femicide and child homicide from a sample of mortuaries for 2009 (Abrahams, Mathews, Jewkes, Martin, & Lombard, 2012; Mathews, Abrahams, Jewkes, Martin, & Lombard, 2012).

In addition to the PIMSS, all-cause mortality deaths were collected from death certificates for all six health districts in the Western Cape through a collaboration between the Provincial Department of Health (DoH), the City of Cape Town and the South African Medical Research Council (SAMRC), which measured broad-cause mortality trends by district from 2009-2013 (Morden et al., 2016). However, 2013 was the final year for which this information was captured, as the Department of Home Affairs amended the South African Births and Deaths Registration Act in 2014 (Republic of South Africa Births and Deaths Registration Act, No. 51 of 1992). A new death notification form was introduced, with a self-sealing page that may be opened exclusively by a Stats SA official, thus preventing access to copies of the death certificates to DoH and collaborative research organisations. This Act curtailed an initiative to strengthen local mortality surveillance, which could be used to inform public health actions in the Western Cape (Bateman, 2015; Groenewald et al., 2015).

The SAPS data have been criticised in the past for under-reporting (Bruce, 2010; Gould et al., 2012), but are the only current national source of homicide data. Police statistics are often under-reported, as their statistics are based upon whether the public considers the crime worthy of reporting, i.e. the probability of the police tracking and arresting the perpetrator, or whether the crime should be reported for insurance purposes (Institute for Security Studies, 2012). Mathews et al. (2004) conducted a national study of female homicide in 1999 and found that more than 13 per cent of police murder dockets could not be traced.

For transport-related deaths, data from the Road Traffic Management Corporation (RTMC) are considered to be representative of the South African

population but as they utilise data from the SAPS, flaws in the data have been highlighted (Chokotho et al., 2012a). Chokotho et al. (2012a) assessed the under-reporting of road traffic mortality statistics in the Western Cape and identified issues such as missing data, duplication and significant under-reporting of traffic injury deaths. These findings are most likely not confined to the Western Cape. The RTMC collects data from the SAPS through accident report forms from provincial traffic authorities and metropolitan municipalities. They have acknowledged that the use of these multiple data sources could cause duplication of road traffic mortality statistics, which they claim to check when processing the data (Gainewe, 2010).

In addressing South Africa's data deficiencies, the first independent National Burden of Disease (NBD) study provided estimates for mortality and DALYs for 2000 (Bradshaw et al., 2003). South Africa's second NBD study provides mortality trends from 1997 to 2012 and years of life lost for 2012. The related findings on national estimates for causes of death were discussed in section 2.1.2. A comparison of the second NBD study's findings with that estimated for South Africa in 2010 by the Global Burden of Disease (GBD) study (2016), which used extensive modelling of trends in multiple countries and correlations with socio-demographic indicators, found an under-estimation for injury deaths by the GBD study. In particular, road injuries were under-estimated by 40.0% and interpersonal violence by 34.4%. There was an even larger difference in the GBD study's estimates for South Africa's interpersonal violence deaths for 2013, which were under-estimated by 48.6% (Pillay-van Wyk et al., 2016a). This highlights the importance of local empirical studies, such as the Injury Mortality Survey that will be utilised throughout this thesis (Matzopoulos et al., 2015), to inform national burden of disease estimates and trends.

2.7.2 South African data sources for non-fatal injuries

Previous attempts at establishing non-fatal injury surveillance systems in South Africa have proven difficult. However, such *ad hoc* studies were relied upon in subsequent estimates for the burden of injury. In the Western Cape, non-fatal injury data were available for 1990 from the Cape Metropole Study (CMS) (van der Spuy, 1993; Peden, van der Spuy, & Abrahams, 1996; Peden, Marais, Abrahams, & van der Spuy, 1997) and were used to inform the morbidity profile for the 2000 NBD Study (Bradshaw et al., 2003).

Non-fatal injury data for rural areas were available from the Rural Injury Surveillance Study (RISS) conducted in the early 1990s at a sample of hospitals in the West Coast, Cape Winelands and Overberg health districts (MRC National Trauma Research Programme, 1992; Donson & Marais, 2004). No continuous injury surveillance has been implemented since, and rural areas - not only in the Western Cape but throughout South Africa - continue to be neglected when planning injury research.

Matzopoulos, Prinsloo, Butchart, Peden, and Lombard (2006) conducted a rapid assessment of trauma caseloads for secondary and tertiary state hospitals in 1999 to inform non-fatal injury trends and ascertain the feasibility of establishing a nationally representative surveillance system. A total of 318 health facilities were identified and 209 (66%) responded to the questionnaire. Trauma caseloads were available from the hospitals' trauma registers for 82 per cent of the respondents, while 18 per cent had to collect data specifically for the study. The responding facilities were weighted in each province for the total sample, which provided an annual estimate of approximately 1.5 million trauma cases nationally. This was considered to be an undercount, since injured patients presenting to primary healthcare clinics, traditional healers, private hospitals and private doctors were not taken into account. It became apparent from this study that it would not be possible for the research team to manage and maintain a national system without considerable financial and logistical support from government.

Subsequently, injury surveillance systems were piloted in only two urban hospitals, GF Jooste Hospital in the Western Cape and Cradock Hospital in the Eastern Cape. Even though injury surveillance was limited to only two hospitals, it was found not to be sustainable as a result of doctor turn-over, insufficient human resources and the absence of a dedicated data co-ordinator/field supervisor within the hospitals (Bopape, 2001; Prinsloo & Matzopoulos, 2002).

In recent years, injury surveillance pilot studies were conducted at Groote Schuur (Schuurman et al., 2011), a large, state, tertiary hospital and Elsies River - a state community health centre (Govender, Matzopoulos, Makanga, & Corrigall, 2012), which are both in the Western Cape. Cross-sectional studies are conducted annually at

Elsies River community health centre and have been expanded to the community health centres in Nyanga and Khayelitsha (Mureithi et al., 2013). Following the one-month pilot study at Groote Schuur Hospital (GSH), a prospective study of trauma admissions from October 2010 to September 2011 was implemented. As it was based on admission records with their own limitations, the study provided mostly demographic and geographic results of non-fatal injury, which at least yielded a picture of the burden of trauma in Cape Town, but had no information on injury outcomes nor any anatomical information, which is essential for injury severity scoring (Nicol et al., 2014). Completion rates of the required variables were low and were attributed to frequent staff turnover and high clinical workloads, which were the same limitations reported more than a decade ago by Bopape (2001), as well as Prinsloo and Matzopoulos (2002). Nicol et al (2014) also indicated that an on-site trauma co-ordinator would be ideal to ensure the information obtained was more complete, which was similar to that reported by Prinsloo and Matzopoulos (2002).

Most of the published, larger non-fatal injury surveillance studies have been conducted in Cape Town, are urban-biased and not nationally representative. Additional published literature was available for the province of KwaZulu-Natal (KZN). Lewis and Wood (2015), used emergency department admission data from Ngwelezane Regional Hospital in north-eastern KZN, to report on major trauma over a five-year period (2009-2013). The emergency department's resuscitation unit maintains a database, which allows for the reporting of trauma trend data within the region. Patient age and sex, injury type, length of hospital stay and eventual mortality were recorded. The leading causes of injury were stabbings, motor vehicle-related blunt force trauma, violence-related head injuries, and gunshot wounds. As a large regional hospital which treats major trauma, the findings for the leading injury types in eastern KZN were similar to that reported by Nicol et al. (2014) for GSH in Cape Town, where assault by sharp- and blunt object assaults and motor vehicle collisions were the leading non-fatal injuries.

Also in KZN, Lutge et al. (2016), used District Health Information System (DHIS) data from 2012 to 2014 to report on the mechanisms of trauma, admissions to wards, transfers to other hospitals and trauma severity as per triage information. Trauma data were not collected in the DHIS prior to 2012, when the authors

incorporated this information in collaboration with the KZN Department of Health. While this information is now mandatorily collected within this province, it provides a description of trauma incidents based upon totals of aggregated data. It therefore reports a summary count of data and not individual records.

Lutge et al. (2016) may have reported an undercount of the trauma burden in the province, as they did not include information from clinics, where minor injuries are treated. Only specific mechanisms of trauma are recorded, i.e. assault with blunt object, stabbing, gunshot, motor vehicle collisions for occupants and pedestrians and unintentional injury. This list excludes information on attempted suicide and the broad category of unintentional injury does not provide any specific detail on childhood injuries, for which this is the dominant category. No age breakdown by mechanism of trauma was reported, as the DHIS only records data for under-five years and five years and older, which is a serious information gap in the system. In contrast to the hospital data reported by Lewis and Wood (2015), blunt-force assaults are reported to be the leading injury type in the KZN province and all motor vehicle collision categories combined rank second, followed by stabbings.

An electronic surgical registry was also implemented by the Pietermaritzburg Metropolitan Trauma Service (PMTS), which provides strategic leadership in trauma care to the city of Pietermaritzburg and the western rural health-districts of KZN (Laing et al., 2014). The electronic surgical registry captures admitted trauma patient data from a standardised paper-based form after discharge. Injury-outcomes data are therefore available from this registry, as well as demographics, admission vital signs and categorisation of anatomical injuries. Injury severity scores are also retrievable, as well as information on operative interventions and complications. Laing et al. (2014) reported on the data captured for 2012 at a tertiary hospital (Greys), and it appears that this registry is also active at the regional hospital (Edendale). It is not apparent however, whether this electronic registry exists within the district hospital (Northdale) or within the three private hospitals, the two other regional hospitals in Western KZN or the 19 district hospitals mentioned by the authors. It is, however, a valuable source of non-fatal injury and outcomes information.

In summary, there is no consistent or sustainable database on non-fatal injury available nationally. A review of the literature identified some similarity in the ranking by type of injury in both urban and rural areas. The data collection of non-fatal injuries is not within the trauma-staff's job description or daily routine activities, and the magnitude of non-fatal injuries make it administratively burdensome to collect. State and private hospitals within South Africa have varying trauma registries and electronic systems to record trauma patient admissions and often have a wealth of data but do not necessarily write-up the information for publication. Collaborative efforts are needed, such as those by Nicol et al. (2014), Laing et al. (2014), Lewis and Wood (2015) and Lutge et al. (2016), between researchers and state tertiary and secondary hospitals, to get a representative picture of non-fatal injury in urban and rural areas.

2.8 International initiatives for sustainable data collection

It is evident from the aforementioned literature, particularly for the surveillance of fatal injuries that a number of efforts have been made to collect injury mortality data, yet none have been sustainable. The WHO manual for fatal injury surveillance in mortuaries and hospitals (WHO, 2012b), lists the attributes of a good surveillance system as: the willingness of staff and institutions to participate; the simplicity of operating the surveillance system and the accessibility of data to stakeholders; the accuracy of reporting on different data elements; timeliness of an event and inclusion in the surveillance system; the ability to detect, capture and report cases; representativeness of the surveillance system over time and over a given population; the flexibility and adaptability of the system to changing needs and new demands; and, the stability or dependability of a system. The review of the South African fatal injury data sources has identified that some of the attributes mentioned previously were lacking within the different data sources discussed. Not having an adequately established surveillance system or reliable vital registration data makes it difficult to ascertain the true magnitude of the injury burden in South Africa. This is an obstacle to developing relevant and evidence-based injury prevention programmes and to generating adequate funding for these from government and other agencies.

For most high-income countries, mortality data are available through established vital registration systems (Bhalla et al., 2010). The United States has an established National Centre for Health Statistics (NCHS), which, as the country's principal health

statistics agency (CDC, 2017a), sources data from birth and death certificates, patient and medical records, personal interviews, physical examinations and laboratory tests, and from healthcare facilities and providers. In addition, a National Violent Injury Statistical System (NVISS) was launched in 1999. The aim was to monitor the magnitude and characteristics of violent deaths, to routinely share the data with public health and law enforcement officials and policy makers, to ensure that violence prevention programmes are implemented and evaluated; and to strengthen partnerships among stakeholders.

Through funding from the CDC in 2002, this initiative evolved into the National Violent Death Reporting System (NVDRS). This enabled the collation of violent death information from death certificates, forensic pathology records, police reports, supplementary homicide reports and crime laboratory data into an anonymous database, fully operational in 16 states by 2009 (Karch, Logan, McDaniel, Parks, & Patel, 2012) and 40 states by 2017 (CDC, 2017b). This was the first system to link multiple sources of data to contextualize the events surrounding each violent death (Karch, Lubell, Friday, Patel, & Williams, 2008; Karch et al., 2012) but is not fully representative of all states.

It is not only in high-income countries, however, that sustainable data-collection systems have been developed. The high rates of injury and violence in the city of Cali, Colombia prompted the initiation of a municipal mortality surveillance system by the city's Mayor in 1993 (Guerrero & Concha-Eastman, 2001). This was part of a programme of development, security and peace, referred to by the acronym DESEPAZ. The data collected were reviewed in weekly meetings of the city security council and further statistical analysis led to policy planning and co-ordinated intervention efforts. Initially, the improvement of police functioning was addressed through salary increases, educational opportunities and incentives for housing construction. Risk factors for urban violence were examined and guiding principles were adopted based on multi-causality and the need for multiple social interventions (Guerrero & Concha-Eastman, 2001; Gutierrez-Martinez, Del Villin, Fandiño, & Oliver, 2007).

The municipal mortality surveillance system initiated by the Mayor of Cali was expanded in the early 2000s by the CISALVA Institute, a research centre on health and violence at the University of Valle into 21 crime observatories in mid-sized municipalities of Western Colombia. The three basic functions of an observatory are: the collection of data, analysis of data and public dissemination (Gutierrez-Martinez et al., 2007). An observatory collects data from multiple sources (i.e. surveillance, hospital records, forensic reports, police data, etc.) to monitor health trends and identify gaps in health information; and integrates population-based data and institution-based data from health and other sectors (Caiaffa et al., 2013). The objective for developing these observatories was to strengthen municipal and regional governments by improving their response to high levels of violence. This included the need for reliable, low-cost, efficient and appropriate crime information systems; and support for public policy development and updated skills such as crime mapping procedures. For this to be sustainable, it required political will to use violence information in decision making; institutional co-ordination from police, forensic medicine, public prosecution offices and public health officials in contributing to the validation of data and formulating violence reduction and prevention policies at analysis committee meetings; and, capacity building and follow-up on intervention strategies (Gutierrez-Martinez et al., 2007).

In summary, this literature review identified homicide as the leading cause of injury death in South Africa - nearly six times the global rate. The review also identified that the cause of injury death may differ by urban or rural area for both high- and middle-income countries. It identified a gap in the literature for the differing urban-rural associations for vulnerable groups in South Africa, as the existing surveillance data were urban-biased, and vital registration data for injuries were misclassified and incomplete. The risk factors for homicide were reflected upon, and frameworks for evaluating the quality of injury mortality data were explained; which highlighted South Africa's data deficiencies for injury mortality and morbidity nationally. A review of the literature revealed a paucity of nationally representative data for injuries, together with the existence of only superficial descriptive analysis. More advanced statistical methods had not been used in the analysis of injury and homicide risk. Hence, the IMS data will be used for this thesis. The findings of this chapter will inform the rest of this thesis; and will be discussed specifically in Chapter 3 (Aims and Objectives).

3 AIMS AND OBJECTIVES

The overarching aim of this thesis is to utilise national data for injury mortality in South Africa, in order to conduct advanced statistical analyses to identify urban-rural differences for injury deaths. This will be addressed through the following objectives:

Objective 1: To review available literature on injury mortality and associated risk factors for homicide

The literature review in Chapter 2 identified that injury-related deaths in South Africa accounted for nearly 10% of all causes of death. Homicide and road traffic deaths were identified as the eighth and ninth leading single causes of all deaths (which includes natural deaths), and even though homicide rates declined remarkably between 1997 and 2012 (Msemburi et al., 2016), it is still approximately six times higher than the global rate of 6.4 per 100 000 population (WHO, 2017b). Particular urban-rural differences for injuries and risk factors for homicide were identified and were used to inform Objectives 4 and 5, which will be described in this chapter. South Africa's high number of injury deaths and non-fatal injuries have made the capturing of accurate statistics very challenging (Matzopoulos et al., 2006; Matzopoulos, 2012; Nicol et al., 2014), which was the focus of:

Objective 2: To conduct a situational analysis of injury data sources in South Africa

A review of South African injury data sources in Chapter 2 highlighted challenges in the coverage and completeness of the vital registration system and misclassification of deaths. Although the completeness of vital statistics has improved to levels that exceed 90% (Joubert et al., 2013; Dorrington, Bradshaw, Laubcsher, & Nannan, 2015), the misclassification of injury deaths in particular persist (Westwood, 2000; Burger et al., 2012). Reasons for this were discussed in Chapter 2 and current vital statistics still classify 63% of non-natural or injury deaths as other unintentional (Stats SA, 2015), while alternative sources indicate that homicide and transport are the leading causes of injury death (Butchart et al., 2001; Bradshaw et al., 2003; Matzopoulos, 2005; Norman et al., 2007; Msemburi et al., 2016; Pillay-van Wyk et al., 2016a; Prinsloo et al., 2017).

The dearth of reliable vital registration data for injury deaths led to injury mortality surveillance initiatives since the 1990s, but these surveillance systems were met with challenges along the way, and could not be sustained, as discussed in Chapter 2. Other data sources and their challenges discussed were those of the SAPS and RTMC and other initiatives to capture non-fatal injuries. Due to the challenges of capturing reliable cause of death statistics for injuries, an Injury Mortality Survey (IMS) was conducted (Matzopoulos et al., 2012), with sampling representative of metro- and non-metro areas (see Chapter 4: Methods) to get an accurate profile of urban and rural areas. The data derived by the IMS will be utilised in this thesis and Objective 3 will assess the quality of these data.

Objective 3: To evaluate the quality of the survey data used for this thesis

This objective will be addressed in section 5.1 of Chapter 5, which will assess the quality of the IMS data utilised in this thesis. The framework developed by Rao et al. (2005) as discussed in Chapter 2, will be used to assess the data according to the attributes: *generalizability, reliability, validity and policy relevance.* This will be done through a basic bivariate analysis of the injury mortality proportions, which will include the variable categories: *age, sex, race, manner of death, province* and *metro-/non-metro area*. Chapter 5 will also include a validation of the data by alternative data sources.

To further achieve the overarching aim, the following will be considered:

Objective 4: To characterize the variables driving the urban-rural differences of fatal injuries in South Africa

Section 5.2 in Chapter 5 will begin to address this objective, by calculating age-specific rates, to account for the strong age pattern observed for injury deaths between 15-44 years both globally (WHO, 2002, 2010b, 2014a, 2017a) and in South Africa (Norman et al., 2007; Matzopoulos et al., 2015). Age-standardised rates by sex, race, and metro-/non-metro area for each manner of death will be calculated to account for the effects of different age structures for metro- and non-metro area populations. This will help identify any significant urban-rural differences for the explanatory variables and provide insight to the likely associations that can be expected in the multiple correspondence analysis and the injury mortality profiles of the multinomial logistic

regression for Chapter 6. Examining the injury mortality profile is important for prioritising relevant interventions to reduce the injury mortality rates for South Africa.

Chapter 6 will use multiple correspondence analysis as an innovative approach to explore proportional differences and illustrate any observed associations between the variable categories. This is prior to identifying the relevant variables to include for the multinomial logistic regression modelling, to determine any statistically significant associations between independent variables and the outcome proportions. This will compare the explanatory variables for homicide, suicide and transport-related deaths relative to other unintentional injury deaths.

The literature review in Chapter 2 reflected on the fact that urban-rural differences for injury deaths in high-income countries were different to those for low- to middle-income countries. For high-income countries such as England and Wales, Australia and the United States, transport-related injuries was identified as the leading cause of death (Gartner et al., 2008; Mitchell & Chong, 2010; Myers et al., 2013), while for China as an upper middle income country, this was suicide (Yang et al., 2004; Liu et al., 2012), as opposed to homicide in low- to middle-income countries (Reichenheim et al., 2011; Eisner, 2015; WHO, 2017a). The urban-rural difference for injury deaths in high-income countries, appear to be driven by the high rate of transport-related deaths in rural areas. Reasons for this were discussed in Chapter 2. Hence, the multinomial logistic regression analysis will include the explanatory variables age, sex, race and metro/non-metro as reported by the injury mortality literature, to investigate the following hypothesis:
HYPOTHESIS 1) *Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas.*

It is expected that homicide will be higher in metro/urban areas, based on the literature for low-to-middle-income countries (Reichenheim et al., 2011; Matzopoulos et al., 2015). Hence, Objective 5 will be: *To determine the explanatory variables for homicide in urban- and rural areas*

The explanatory variables for the urban-rural distribution of homicide nationally, will be investigated according to the following hypotheses, as determined by a review of the risk factors for homicide discussed in the literature review of Chapter 2:
HYPOTHESIS 2) *Age, sex and race are independently associated with* ***homicide*** *in both metro- and non-metro areas* (Matzopoulos, 2012; Matzopoulos et al., 2015);

Further sub-hypotheses will be investigated with regards to race for the following reasons:

South Africa has never had any nationally representative source of homicide by race, which has resulted in conflicting statements as to whether Blacks or Coloureds had the highest risk for homicide (Leggett, 2004b; Leggett, 2004a; Thomson, 2004; Seedat, Van Niekerk, Jewkes, Suffla, & Ratele, 2009; Matzopoulos, 2012). The data utilised for this thesis provides the first nationally representative sample, which will provide some clarification on whether Blacks or Coloureds have a higher risk for homicide. The initial report of this data found the homicide rate in metro areas was highest for Blacks, while the homicide rate in non-metro areas was higher for Coloureds than Blacks (Matzopoulos et al., 2015). Hence, the sub-hypotheses will consider that:
SUB-HYPOTHESIS 2.1) *Blacks experience a higher risk for homicide in metro areas than Coloureds; and Coloureds experience a higher risk for homicide in non-metro areas than Blacks*.

The male homicide rate was 1.3 times higher in metro areas than non-metro areas, while there was not a great difference between the metro- and non-metro homicide rate for females (Matzopoulos et al., 2015), which formed the basis for:
SUB-HYPOTHESIS 2.2) *The risk of homicide among males relative to the risk among females is greater in metro areas than in non-metro areas*.

Other explanatory variables:

Day of week is used as a proxy for alcohol consumption, which has been linked to increased rates of violence (Graham & Livingston, 2011; Matzopoulos, 2012). Data for five South African cities for 2001-2005 indicated that the risk for homicide was higher over weekends (Matzopoulos et al., 2014). Thus, day of week will be considered as an explanatory variable for homicide in:

HYPOTHESIS 3) *Day of week is independently associated with homicide* (Matzopoulos, 2012);

South African studies have shown an association between firearm availability and the rate of firearm homicide (Matzopoulos et al., 2014; Matzopoulos et al., 2018), which forms the basis for:
HYPOTHESIS 4) *Metro/non-metro differences for homicide can be explained by firearm use* (Matzopoulos et al., 2014);

Homicide rates were reported to be higher in metro-areas than non-metro areas (Matzopoulos et al., 2015). The regression analysis and age-standardised rate calculations for Chapter 7 will be exclusive to homicide and its explanatory variables in South Africa.

4 METHODS

The methodological aspects of this thesis are discussed according to: 4.1) Data sources and role of the PhD candidate, 4.2) the Injury Mortality Survey (IMS) - study design and study population, 4.2.1) metro-and non-metro area classification, 4.2.2) sampling, 4.2.3) data capture, 4.2.4) data management and quality control, 4.2.5) variables, 4.2.6) data cleaning and estimation, 4.2.7) data analysis for the IMS, 4.2.8) population estimates and 4.2.9) rate calculations. Section 4.3 pertains to the thesis results chapters' methods, which in addition to basic analysis of proportions, utilizes advanced sophisticated analysis of which the methods are described in section 4.3.1) multiple correspondence analysis, 4.3.2) multinomial logistic regression analysis, 4.3.3) injury mortality rates and 4.3.4) logistic regression analysis. Section 4.4 concludes the Methods chapter with a section discussing ethics and confidentiality.

4.1 Data sources and role of the PhD candidate

This study utilizes the data of the Injury Mortality Survey, for which descriptive analysis and rates have been reported (Matzopoulos et al., 2013; Matzopoulos et al., 2015), to address the aims and objectives mentioned in Chapter 3. The PhD candidate acted as project manager for the IMS study and was responsible for the initial design of the questionnaire (Figure I in Appendix I), in consultation with the principal investigator and study collaborators and contributed to the concept proposal. The PhD candidate supervised the admin officers, fieldwork co-ordinator and biostatistician appointed for the study logistics, permissions to access records at mortuaries, fieldwork activities and data management of the IMS. The PhD candidate and study collaborators monitored the quality of the live data capture during the course of the study, analysed the data and contributed to the report (Matzopoulos et al., 2013) and capstone paper (Matzopoulos et al., 2015).

This is a thesis by manuscript and not a thesis based on a compilation of prior published work. The thesis consequently includes some limited content from the following publications arising from the IMS data. The PhD candidate's role on each paper is clarified:

1. Matzopoulos R, Prinsloo M, Bradshaw D, Pillay-van Wyk V, Gwebushe N, Mathews S, Martin L, Laubscher R, Lombard C and Abrahams N. (2013). The Injury Mortality Survey: A national study of injury mortality levels and causes in South Africa in 2009. Tygerberg: Medical Research Council.

-the PhD candidate's role in this study was described as above and her specific input to the report included leading the analysis with the principal investigator and leading aspects of the report write-up.

-the PhD candidate was also first author to various conference presentations on the 2009 IMS data.

2. Matzopoulos R, Prinsloo M, Pillay-van Wyk V, Gwebushe N, Mathews S, Martin L, Laubscher R, Abrahams N, Msemburi W, Lombard C, Bradshaw D. (2015). Injury-related mortality in South Africa: A retrospective descriptive study of postmortem investigations. *Bulletin of the World Health Organization*; 93(5): 303-13. Epub 2015 Mar 13. DOI: 10.2471/BLT.14.145771.

-the PhD candidate and principal investigator led the analysis in consultation with the biostatistician and contributed to the write-up and final additions to changes as suggested by the reviewers of the paper.

3. Prinsloo M, Matzopoulos R, Laubscher R, Myers J, Bradshaw D. (2016). Validating homicide rates in the Western Cape Province, South Africa: Findings from the 2009 Injury Mortality Survey. *South African Medical Journal*; 106(2):193-5. Epub 2016/01/30.

-the PhD candidate was responsible for the initial concept, data analysis, constructing the first draft of the paper, incorporating co-authors comments and final submission to the journal with reviewer's comments incorporated.

4. Prinsloo M, Bradshaw D, Joubert J, Matzopoulos R and Groenewald P. (2017). South Africa's vital statistics are currently not suitable for monitoring progress towards injury and violence Sustainable Development Goals. *South African Medical Journal*, 107(6), 470-471.

-the PhD candidate was responsible for the concept and first draft of the paper, the addition of co-authors comments and final submission to the journal.

5. Matzopoulos R, Simonetti J, Prinsloo M, Neethling I, Groenewald P, Dempers J, Martin LJ, Rowhani-Rahbar A, Myers J, Thompson ML. A retrospective time trend study of firearm and non-firearm homicide in Cape Town from 1994 to 2013. *South African Medical Journal* 2018; 108 (3):197-204.
doi:10.7196/SAMJ.2018.v108i3.12756

-the PhD candidate was initially involved in the data management of the surveillance data for 1999-2005 used for this paper and acted as project co-ordinator for the 2005 data.

- the PhD candidate was responsible for collating the 1994-2013 database for this paper, cleaning of the data and input to the analysis done by the statistician assigned to this paper.

- the PhD candidate contributed to the write-up of the paper and approval of the final version.

The sections to follow briefly explain the sampling, data capture, data management and quality control processes of the IMS.

4.2 The Injury Mortality Survey - study design and study population

The Injury Mortality Survey was a retrospective record review of deaths that occurred in 2009 from a nationally representative sample of mortuaries in eight provinces (Matzopoulos et al., 2013; Matzopoulos et al., 2015). The study was conducted in 2011, but the data for 2009 had to be collected, to ensure that most police investigations and court cases pertaining to non-natural deaths were complete, and that all post mortem folders were available in the sampled mortuaries at the time of data collection. Information was extracted from forensic pathologist post-mortem reports and data for the Western Cape was available from the existing Provincial Injury Mortality Surveillance System (PIMSS) (Matzopoulos et al., 2010). The study population was all persons who died as a result of non-natural causes in South Africa.

4.2.1 Metro and non-metro area classification

The designation of metro- and non-metro areas were based upon the 2007 Community Survey's categorisation of municipalities for each province (Stats SA, 2007). The six metropolitan areas were: Cape Town, Ethekwini (Durban), Ekurhuleni (East Rand), Johannesburg, Tshwane (Pretoria) and Nelson Mandela (Port Elizabeth). The Free State province, Limpopo, Mpumalanga, North West and Northern Cape provinces did not have any designated metropolitan areas and were classified as non-metro.

4.2.2 Sampling

The multistage stratified cluster sample was drawn for the eight provinces using mortuaries as the primary sampling unit (cluster). A representative sample of mortuaries was drawn from a sampling frame of 106 mortuaries (57 274 folders) across eight provinces in South Africa in 2009. This resulted in the selection of 45 mortuaries, which were stratified by metro- and non-metro area and mortuary size. Mortuary size categorisation was established by the *Female and Child Homicide study's* sampling frame (Abrahams et al., 2012; Mathews et al., 2012).This included small mortuaries (up to 500 bodies), medium (501–1 500 bodies) and large (>1 500 bodies). Table 3 indicates the total number of mortuaries and post mortem folders for the eight South African provinces for 2009 and those selected for the survey in brackets. Secondary data for the Western Cape deaths in 2009 were requested from the collaborators of the Provincial Injury Mortality Surveillance System, which captured deaths from all 18 mortuaries.

Table 3. Sampling frame for the selected mortuaries for the 8 provinces

		Mortuaries					Folders				
		Metro		Non metro		Total	Metro		Non metro		Total
		Large	Medium	Medium	Small		Large*	Medium	Medium *	Small	
Strata 1	EC		5 (2)	6 (2)	3 (2)	14 (6)		3817 (1307)	4986 (2299)	667 (422)	9470 (4028)
Strata 2	FS			3 (3)	3 (2)	6 (5)			2892 (2892)	1203 (724)	4095 (3616)
Strata 3	GT	4 (2)	6 (6)			10 (8)	10056 (5212)	5746 (5746)			15802 (10958)
	KZN	2 (2)	1 (1)	5 (2)	31 (6)	39 (11)	4017 (4017)	1109 (1109)	3696 (1843)	4860 (1338)	13682 (8307)
Strata 4	LP			3 (2)	8 (2)	11 (4)			2195 (1623)	2200 (549)	4395 (2172)
	MP			2 (2)	10 (2)	12 (4)			1281 (1281)	2841 (564)	4122 (1845)
	NW			3 (2)	5 (2)	8 (4)			2256 (1606)	1722 (511)	3978 (2117)
	NC			1 (1)	5 (2)	6 (3)			658 (658)	1072 (285)	1730 (943)
	Total	**6 (4)**	**12 (9)**	**23 (14)**	**65 (18)**	**106 (45)**	**14073 (9229)**	**10672 (8162)**	**17964 (12202)**	**14565 (4393)**	**57274 (33986)**

*Second level of sampling with every second folder selected. Source: Matzopoulos et al. (2013)

A second level of sampling was applied for the sampled mortuaries. For small mortuaries and medium metro mortuaries all records for 2009 were included, but in the large metro- and medium non-metro mortuaries every second folder was selected for inclusion. This resulted in forty-five mortuaries being selected for an expected sample of 22 733 survey records. The Provincial Injury Mortality Surveillance System data for the Western Cape province completed the national sample (Matzopoulos et al., 2010). The metro-area mortuaries are in reference to those located in urban areas and the non-metro area mortuaries are located in rural areas. The terms metro/urban and non-metro/rural are used interchangeably throughout this thesis.

4.2.3 Data capture

Initially, an Excel-based data collection form (Figure I in Appendix I) was designed to formulate the required information for data capture. The data collection form was converted into a mobile phone application by an external company ("Mobenzi Researcher", 2011) and the data were captured on-site and uploaded to a central web-based data platform. This allowed for ongoing monitoring of data-collection activities, quality control and data cleaning by the national fieldwork coordinator, project manager and biostatistician.

Besides the post-mortem reports, police reports and hospital records that appeared in case folders were used as ancillary documentation to extract the required information. The pathologist overseeing access to the mortuaries in KwaZulu-Natal only allowed data collection from the register and missing information and queries on external cause and manner of death were obtained from forensic pathologists at the selected mortuaries post data collection.

To test interrater reliability, two fieldworkers independently collected data from the same folder, on the same day, for 5 percent of the sample. Every 20th folder was reserved for independent capture by another fieldworker. This was done to determine if the data collected in the study was a correct representation of the measured variables.

Blood alcohol data were collected from the post-mortem folders where available, but further results could only be sourced from the State chemical laboratory in Cape

Town. The blood alcohol data were not included in this analysis, as it was not nationally representative.

4.2.4 Data management and quality control

Data quality checks were incorporated in the data capture application. As example, consistency between manner of death and cause of death, age limitations for suicide, accuracy of capturing the death registration number and automated skips based on the manner of death were incorporated. Once the fieldworkers entered the data, the records were uploaded to a central web-based data platform. The project manager, biostatistician and national fieldwork coordinator received email notifications if the fieldworkers incorrectly entered data. This enabled the biostatistician to correct certain records and the national fieldwork coordinator to address the errors with the fieldwork teams. The time and date of record capture and the number of records captured per day for each fieldworker were also registered. Hence, the national fieldwork coordinator could monitor individual fieldwork performance.

The proportion of potential agreement beyond chance between two data collectors, extracting data from the same folder on the same day, was determined using Cohen's Kappa statistic (Cohen, 1968), which range from -1 to +1, where zero represents the agreement that can be due to random chance or no agreement and 1 represents perfect agreement. 0.01–0.20 represents none to slight agreement, 0.21–0.40 as fair, 0.41– 0.60 as moderate. 0.61-0.80 is considered substantial agreement. The recommended level of agreement is 0.80 and above as near perfect agreement. The study results are likely to be questionable if the Kappa statistic is 0.60 and below (McHugh, 2012).

4.2.5 Variables

The variables recorded for the survey included cause of death (i.e. natural, non-natural, foetus or undetermined). For non-natural deaths, the manner of death was recorded (i.e. homicide, suicide, transport, other unintentional or undetermined), as well as the external cause of death (i.e. firearm, sharp force, strangulation, hanging, pedestrian, driver, burns, falls, drowning, etc.). Age, sex, race and date of death were also reported. The terms non-natural deaths and injury deaths are used interchangeably throughout this thesis.

4.2.6 Data cleaning and estimation

The data were exported from the web-based data platform to an Excel spreadsheet, cleaned and analysed. The IMS recorded 22 583 deaths from the sample of 45 mortuaries within the eight provinces in 2009. The anonymised PIMSS data were merged with the data captured by the IMS, adding a further 9 418 deaths from the Western Cape province. A total of 32 001 unweighted deaths were thus recorded (this included the Western Cape deaths) for the survey.

Analysis weights were applied to account for the selection probabilities of mortuaries within survey strata and the sample realisation. The weight calculations were based on the number of mortuaries in each metro/non-metro area categorised by strata size, as indicated by Table 3 (Matzopoulos et al., 2013). The 32 001 unweighted deaths have been weighted to a total of 66 693 deaths for South Africa in 2009. Of these, 52 493 (78.7%) were non-natural or injury-related deaths and 11 249 (16.9%) were natural (Figure 4).

For foetuses and deaths from natural causes, only basic demographic information was captured. As not all natural deaths are subject to a post-mortem examination, it should be noted that this is not a true reflection of the cause of death profile for South Africa. Burden of Disease estimates with base information from Stats SA underlying cause of death data, additional injury survey estimates and disease modelling have indicated that approximately 9.6% of the more than 500 000 deaths recorded annually in South Africa were non-natural or injury deaths, with the remainder classified as natural deaths (Msemburi et al., 2016).

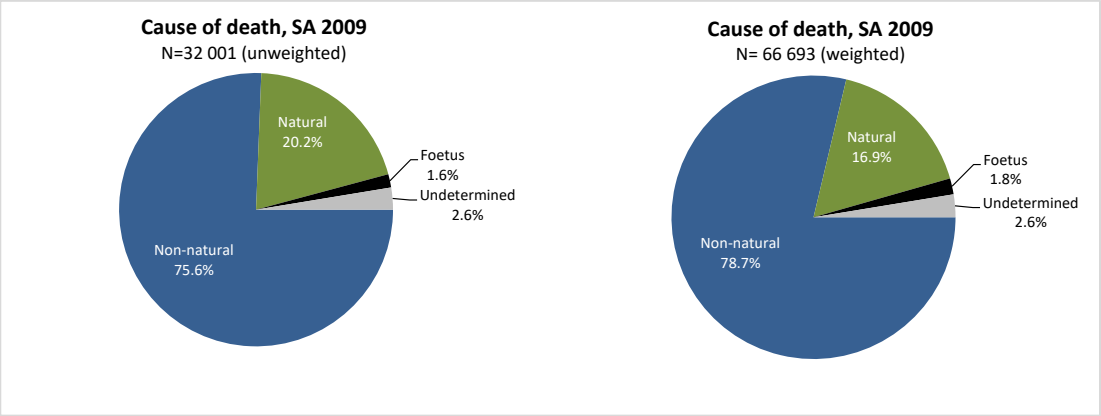

Figure 4. Cause of death (unweighted and weighted analysis), IMS 2009
Source: Matzopoulos et al. (2013)

4.2.7 Data analysis for the IMS

National estimates for the proportion of deaths for homicide, suicide, transport deaths, other unintentional injury deaths and undetermined injury deaths were computed in Stata (Stata/IC 13, 2013). A breakdown of fatal injuries by manner of death and province is shown in Table I of Appendix I. Section 4.3 of this chapter will report on the data analysis for the thesis.

4.2.8 Population estimates

The 2007 Community Survey (Stats SA, 2007) population breakdown was used to obtain the metro/non-metro populations. Mid-year population estimates were generated for 2007 and 2009 using the Actuarial Society of South Africa (ASSA2008) model (Dorrington, 2013), with an estimated growth rate. Municipalities in the 2007 Community Survey were categorised as metro or non-metro areas for each province. A scaling factor, to adjust for the differences in the ASSA2008 estimates and the Community Survey estimates, was calculated using the ASSA2008 estimates for mid-February 2007 and the Community Survey estimates for mid-February 2007. The scaling factor was used to adjust the Community Survey 2007 metro and non-metro populations. The growth rate was applied to the adjusted Community Survey 2007 metro and non-metro populations to produce mid-year population estimates for 2009 (see Table II and Table III in Appendix I for actual values by province, race and metro-/non-metro area).

Figure 5 illustrates the racial distribution by metro- and non-metro area for the South African population. The Black population constitute the large majority and mostly reside in the rural/non-metro areas of South Africa. The Coloured population have a relatively even distribution between metro- and non-metro areas, while Asians and Whites largely reside in metro-areas.

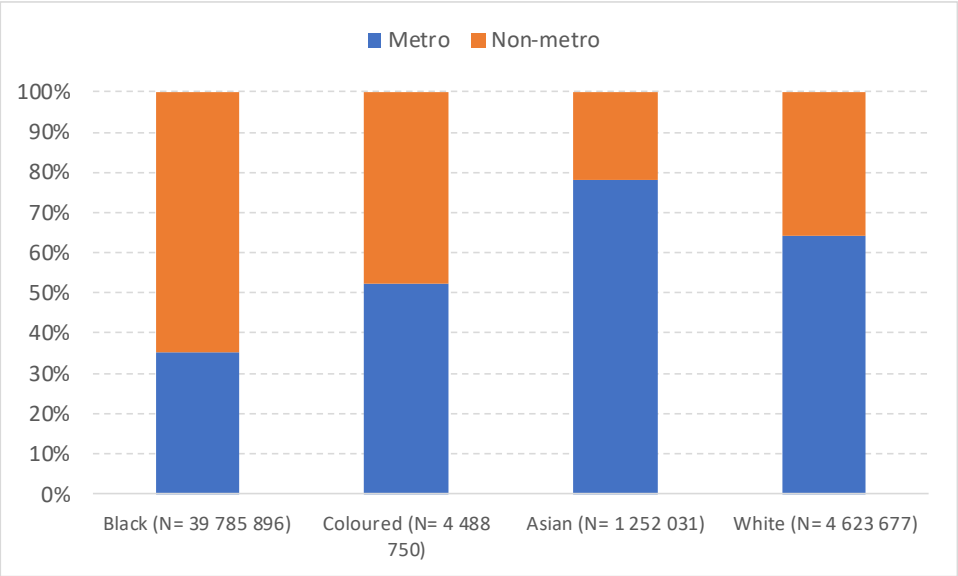

Figure 5. Distribution of SA population by race and metro-/non-metro area, 2009 (N= 50 150 354)

4.2.9 Rate calculations

Mortality rates were calculated using 2009 mid-year population estimates for South Africa, with denominator data from the ASSA2008 model (Dorrington, 2013) and numerator data from the IMS, as described in section 4.2.8. Age-standardised rates (ASR) were calculated from age-specific mortality rates using the WHO world standard (Ahmad et al., 2001). In the burden of disease/global health statistics field, ASR are generally used as the standard for comparison for populations with different age structures –and are used in other South African studies such as the SA NBD.

4.3 Thesis chapter analyses

The thesis will utilize the Injury Mortality Survey data (Matzopoulos et al., 2013; Matzopoulos et al., 2015) to fulfil the aims and objectives described in Chapter 3.

Chapter 5 will address Objective 3: *to evaluate the quality of the survey data used for this thesis,* and is a basic analysis of the data and an evaluation of data quality, utilising the framework developed by Rao et al. (2005), as described in section 2.6 of Chapter 2 of this thesis. In addition, it will start to address Objective 4: *to characterize the variables driving the urban-rural differences of fatal injuries in South Africa,* by presenting the unadjusted mortality proportions based on the use of numerator data (death counts) to describe the metro/non-metro injury mortality profile as part of the initial investigation of associations between the variables.

Age-specific and age-standardised injury mortality rates will then be calculated for a population based comparison of associations between manner of death by age, sex, race and metro-/non-metro area variables for 2009.

Chapter 6 will also address Objective 4: *to characterize the variables driving the urban-rural differences of fatal injuries in South Africa,* and utilise multiple correspondence analysis and multinomial logistic regression analysis, as described in sections 4.3.1-4.3.2, to address Hypothesis 1: *Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas.*

Chapter 7 will address Objective 5: *to determine the explanatory variables for homicide in urban- and rural areas.* The focus is on the explanatory variables of homicide in South Africa; and a set of hypotheses are used to explain the urban-rural difference for homicide utilising regression analysis, as described in section 4.3.3. Age-standardised rates were calculated for the leading external causes of homicide and a breakdown by firearm- and non-firearm homicide.

4.3.1 Multiple correspondence analysis

The multiple correspondence analysis (MCA) in Chapter 6 will be used to identify possible associations between the manner of death by age, sex, race and metro/non-metro and is regarded as exploratory, prior to the selection of variables for the multinomial logistic regression, which will be used to evaluate the statistical significance of these associations. The multiple correspondence analysis, specifying the *proc corresp mca* command in SAS and using the weighted survey data, will graphically illustrate the relationships among the variable response categories. It locates all the variables in a Euclidean space (SAS Institute Inc, 2010), based on Euclidean geometry employed by Euclid, a Greek mathematician around 300 B.C. (Encyclopaedia Britannica, 2018). The two dimensions of this space are plotted to examine the category associations (SAS Institute Inc, 2010). This technique is designed for categorical variables, whose categorical nature is preserved as the analysis is conducted at the response categories and not at the variable level. For the multiple correspondence analysis the response categories for manner of death are homicide, suicide, transport and other unintentional injury deaths. The output of the

analysis is a graphical illustration of a contingency table that identifies the most prominent relationships among variable response categories, which would otherwise not be detected through a pairwise analysis (Sourial et al., 2010).

According to Sourial et al. (2010): "the closer the response category's vector location is to the origin, the more similar the response profile is to the average profile". The origin in this instance refers to the "zero" intersection on the horizontal and vertical axis. The further the response categories are from the origin, the more discriminating they are. The closer the response categories are to the origin, the less distinct they are likely to be, with nothing to differentiate them within the dataset. The percentage indicated on Dimension 1 and Dimension 2 of an illustrated plot, is an indication of the percentage variance explained through visualization of the data. This is illustrated in Chapter 6. Within a large data set there is a greater chance that the illustration does not summarize all the important details; hence the percentage variance could be low. There would be a consequent risk that a category could appear as indistinct in an illustration with a low percentage variance, when it could be distinct within the greater data set (Bock, 2017).

4.3.2 Multinomial logistic regression analysis

Multinomial logistic regression (MLR) analysis is conducted when the dependent variable is nominal with more than two levels, and can be used to model the associations between independent variables and the outcome proportions. It can provide statistical significance for the associations and be used to predict the proportions of the different outcomes based on the independent variables. MLR provides a logistic model for each outcome against the selected reference outcome that has been fitted simultaneously. While the p-values and the predicted proportions can be interpreted easily from the MLR model, it is difficult to interpret the parameters, i.e. relative risk ratio's from the model directly as they reflect the comparison of the particular outcome in contrast to the reference outcome, ignoring the other outcomes.

In this thesis, the manner of death is considered the dependent variable consisting of homicide, suicide, transport-related and other unintentional injury deaths and reported in Chapter 6. This analysis method was used to determine if the likely associations observed in the MCA for age, sex, race and metro/non-metro were

statistically significant so as to investigate Hypothesis 1. The literature review on injury mortality differences between urban and rural areas also informed Hypothesis 1: *Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas,* and was supplemented by the results of the MCA.

The most useful base- or reference outcome is other unintentional because it is considered to not be different between metro and non-metro areas (Matzopoulos et al., 2015), and hence allows understanding of the contributors to metro/non-metro differences for homicide, suicide and transport-related deaths. Hence, the regression analysis will show the relative risk ratios (RRR) and statistical significance ($p<0.05$) for homicide, suicide and transport-related deaths–relative to other unintentional injury deaths, for age, sex, race and metro/non-metro. The intrinsic value or utility of the MLR is that it can identify significant interaction terms between the variables of interest. This can also be of value in settings where denominator data are not easily available. Reference categories for the variables included in the MLR were 45-59 years, females, Whites and non-metro areas on the basis of ease of interpretation.

The mlogit procedure in Stata (Stata/IC 13, 2013) was used and took into account the survey design and the sampling weights of mortuaries as described earlier, by declaring the survey design for the dataset. To obtain the fit statistics the same model was run without the *svy* command, to exclude consideration of the survey structure. This produced the log likelihood, Likelihood Ratio Chi-square (LR Chi^2), p-value and Pseudo R^2. A post-fit command was run in Stata (*estat ic*) to obtain the Akaike Information Criterion (AIC) (Akaike, 1973) and Bayesian Information Criterion (BIC) (Raftery, 1996). A lower AIC or BIC value indicates a better fit for the model. When the difference is greater than two for the AIC, preference is given to the model with the smaller criterion measure (Hardin & Hilbe, 2007). An increased Pseudo R^2 from the null model to the fitted model also indicates an improvement and a better fit (UCLA Statistical Consulting Group, 2011). The worth of a predictor or explanatory variable is also assessed on the basis of the p-value (with significance level <0.05) from a likelihood-ratio test statistic (Hardin & Hilbe, 2007). The model building approach has been kept simple and limited to two-way interactions for ease of interpretation. The best fit model was used to evaluate Hypothesis 1, derived from the literature together

with the identified associations from the MCA to identify the statistically significant associations.

Due to the difficulty in interpreting the relative risk ratios of this particular modelling, predicted proportions were calculated to reflect the model's findings, firstly by using the *mlogit* command again for each model, followed by the *predict* and *tables* command in Stata. The result tables were used to create a graphic representation of the profiles for each manner of death, when adjusting for age, sex, race and metro-/non-metro area in Chapter 6.

4.3.3 Regression analysis of homicide rates

Following the analysis of the injury profiles (proportions), the homicide rates are investigated in detail, taking the population at risk into account. The base analysis of population based rates is found in Chapter 5.2 Chapter 7 then addresses Objective 5, *to determine the explanatory variables for homicide in urban- and rural areas*, through a series of regression models to address hypotheses 2 to 4 and the relevant sub-hypotheses:

2) *Age, sex and race are independently associated with homicide in both metro- and non-metro areas*

   2.1) Blacks experience a higher risk for homicide in metro areas than Coloureds; and Coloureds experience a higher risk for homicide in non-metro areas than Blacks

   2.2) The risk of homicide among males relative to the risk among females is greater in metro areas than in non-metro areas

3) *Day of week is independently associated with homicide*

4) *Metro/non-metro differences for homicide can be explained by firearm use*

Initially for Chapter 7, a Poisson regression model (Poisson, 1837) was fitted, but indicated over-dispersion of the data. Over-dispersion is caused by an excess variation between response probabilities or counts. It can be recognised by observing that the Pearson X^2 or deviance, divided by the degrees of freedom, is greater than 1. The main concern in over-dispersed data is that it may cause underestimation of standard errors of the estimated coefficient vector. This may cause a variable predictor to appear significant when it is not (Hardin & Hilbe, 2007).

Hence, for the analysis in Chapter 7, a negative binomial regression model (Lawless, 1987; Breslow, 1990) was fitted, using the *nbreg* command in Stata, to account for the over-dispersion. As this command did not take the survey design into account, it was followed by a generalized linear model (GLM) (Hilbe, 1993), using the *glm* command in Stata, with the alpha value of the negative binomial regression model specified. The value of this is that the GLM diagnostics are thus available to assess the model fit. This includes the AIC, BIC, log likelihood and deviance, all of which were described earlier.

Demographic factors, i.e. age, sex and race as explanatory variables of homicide were considered, as were day of week, metro- and non-metro areas, and firearm-/non-firearm homicide. The model's reference categories were: females, 45-59 years, Whites, non-metro, Wednesday and non-firearm.

Relevant two-way interaction terms were included and discussed in Chapter 7. Incidence rate ratio's (IRR) and 95% confidence intervals are reported, along with statistical significance ($p<0.05$) of the models' findings. The IRRs of the relevant interaction terms are graphically displayed.

4.4 Ethics and confidentiality

The University of Cape Town's Human Research Ethics Committee granted ethical approval (Appendix II) (HREC REF: 667/2013) for the analysis of this thesis, which was renewed annually.

The Medical Research Council's Health Research Ethics Committee granted ethical approval for the IMS study. No names of the deceased were captured and the confidentiality of records were maintained throughout the study. Fieldworkers were unable to access the captured records once they were uploaded to the web-based database; the data were encrypted during transmission; and the data were stored on a password-protected database behind the MRC firewall. Fieldworkers were trained by a qualified social worker on how to deal with the traumatic information in the post-mortem folders. Weekly debriefing sessions were arranged for each fieldwork team and a helpline was available to fieldworkers, if they were in need of professional help to deal with any trauma.

5 INJURY MORTALITY SURVEY DATA: EVALUATION OF DATA QUALITY AND BASIC RESULTS

The results of this thesis will be presented in three chapters. This chapter (Chapter 5) will mainly address Objective 3: *to evaluate the quality of the survey data used for this thesis*. It will provide a basic analysis of the data and present the proportions of manner of injury death by metro/non-metro. In addressing Objective 4: *to characterize the variables driving the urban-rural differences of fatal injuries in South Africa*, section 5.2 of Chapter 5 will report the age-specific rates and age-standardised rates to take into account the different population structure between metro- and non-metro areas within South Africa.

To further address Objective 4, Chapter 6 will investigate the metro- and non-metro injury profiles (using numerator data). It will utilise multiple correspondence analysis to illustrate the associations found between the variable response categories for age, sex, race and metro/non-metro with each manner of injury death prior to identifying the relevant variables to include in a multinomial logistic regression analysis to test relevant hypotheses and to confirm any significant associations within the data.

Chapter 7 will address Objective 5: *to determine the explanatory variables for homicide in urban- and rural areas*. It will use a set of hypotheses derived from a review of the literature, to explain any urban-rural difference for homicide rates through negative binomial regression, using generalized linear modelling.

This chapter will utilize the conceptual framework developed by Rao et al. (2005), as discussed in Chapter 2, to assess the data quality for the Injury Mortality Survey (IMS). The dimensions of data quality include 1) the *generalizability/representativeness* of the survey data collected, which will consider the coverage of the data, as per the framework of Rao et al. (2005); 2) the *reliability* of the data, which in the framework refers to the consistency of cause patterns in comparison to expected general levels of mortality. In addition, the framework will be adjusted to include the level of agreement between two fieldworkers capturing the same folder to determine the reliability of the survey data. 3) Content *validity* of the

data will include a comparison of available alternative data sources, as well as the use of poorly defined codes and improbable age dependency or age associations by manner of death. 4) The *policy relevance* of the data will be addressed in the concluding chapter of this thesis; and will take into account the results of the preceding chapters.

5.1 Survey Data Quality

5.1.1 Generalizability/Representativeness

This section will firstly assess the *generalizability* or *representativeness* of the data by determining the population *coverage*. The sampling strategy was described in the methods of Chapter 4. The IMS was representative of mortuaries in urban/rural or metro/non-metro areas; and Table 4 provides an initial, basic distribution of injury deaths by province and metro/non-metro area. All provinces except Gauteng had demarcated rural or non-metro areas and the Eastern Cape, KwaZulu-Natal and the Western Cape had an additional urban or metro-area demarcation. Of the estimated 52 493 injury deaths, 53.2% occurred in non-metro areas. More than two-thirds of injury deaths in the Eastern Cape occurred in non-metro areas, while in KwaZulu-Natal the injury deaths were marginally higher in metro-areas. In the Western Cape, nearly 60% of deaths occurred in metro areas. Free State, Limpopo, Mpumalanga, North West and Northern Cape provinces were exclusively demarcated as non-metro areas.

Table 4. Injury deaths by province and metro/non-metro area, 2009

Province	Metro N (%)	Non-metro N (%)	Total N (%)
Eastern Cape (EC)	2 449 (32.5)	5 078 (67.5)	7 527 (100.0)
Free State (FS)	0 (0.0)	3 155 (100.0)	3 155 (100.0)
Gauteng (GT)	12 964 (100.0)	0 (0.0)	12 964 (100.0)
KwaZulu-Natal (KZN)	5 628 (51.6)	5 289 (48.5)	10 917 (100.0)
Limpopo (LP)	0 (0.0)	3 679 (100.0)	3 679 (100.0)
Mpumalanga (MPU)	0 (0.0)	3 345 (100.0)	3 345 (100.0)
North West (NW)	0 (0.0)	3 421 (100.0)	3 421 (100.0)

Northern Cape (NC)	0 (0.0)	1 529 (100.0)	1 529 (100.0)
Western Cape (WC)	3 543 (59.5)	2 413 (40.5)	5 956 (100.0)
Total	24 584 (46.8)	27 910 (53.2)	52 493 (100.0)

Another criterion under *generalizability/representativeness*, is to assess the *completeness* of deaths within the population covered. Of the estimated 52 493 injury deaths, 2 099 (4.0%) were undetermined (Table 5) and were excluded from further analysis. The exclusion of undetermined deaths did not meaningfully alter the metro/non-metro profile for the injury deaths, as the proportion of deaths that occurred in metro- (46.2%) and non-metro areas (53.8%) (see Table 5 footnote), remained similar to that reported in Table 4.

Table 5. Manner of death by metro/non-metro area, 2009

	Homicide N (%)	Suicide N (%)	Transport N (%)	Other unintentional N (%)	Undetermined N (%)	Total* N (%)
Metro	9 846	2 982	7 317	3 156	1 283	24 584
	(51.7)	(46.1)	(41.2)	(44.1)	(61.1)	(46.8)
Non-metro	9 182	3 488	10 426	3 997	816	27 910
	(48.3)	(53.9)	(58.8)	(55.9)	(38.9)	(53.2)
Total	19 028	6 471	17 742	7 153	2 099	52 493
	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)

**When the undetermined deaths are excluded, there are 23 301 (46.2%) metro deaths and 27 094 (53.8%) non-metro deaths of the 50 394 total injury deaths.*

Figure 6 displays the injury mortality profile, excluding undetermined deaths by metro- and non-metro areas. Homicide was the leading manner of death and as a proportion was higher in metro areas (42.3%) than non-metro areas (33.9%). Transport-related deaths followed closely and was higher in non-metro areas (38.5%) than metro areas (31.4%). Other unintentional injury deaths were marginally higher in non-metro areas and the proportion of suicide was similar for metro- and non-metro areas.

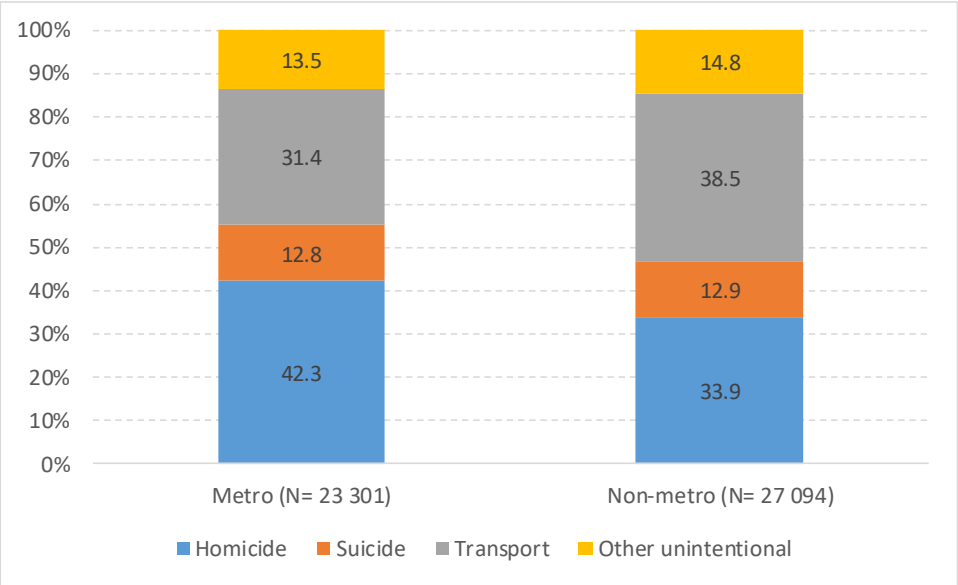

Figure 6. Percent distribution of manner of injury death (excluding undetermined manner) by Metro and Non-metro areas, South Africa 2009

5.1.2 Reliability of the Injury Mortality Survey data

Table 6 and Table 7 presents the cause of death patterns to assess the *reliability* of the data, the second attribute of the framework by Rao et al. (2005). The findings appear to be consistent with that in global and local literature on male homicide for Blacks and Coloureds, on which some of the hypotheses for Chapter 7 are based. The preponderance of males (Table 6) are apparent, with the male to female ratio highest for homicide (nearly six male deaths for every female death) and lowest for other unintentional injuries (2.6:1). The leading manner of death was homicide for males (40.4%) and transport-related for females (42.0%). The sex of the victim was unknown for 126 (0.3%) of the injury deaths captured and these were excluded from further analysis.

Table 6. Manner of death by sex, 2009

Sex	Homicide N (%)	Suicide N (%)	Transport N (%)	Other unintentional N (%)	Total N (%)
Male	16245	5307	13486	5151	40189
	(40.4)	(13.2)	(33.6)	(12.8)	(100.0)
Female	2740	1153	4229	1958	10080
	(27.2)	(11.4)	(42.0)	(19.4)	(100.0)
Unknown	43	10	27	45	126
	(34.2)	(8.2)	(21.8)	(35.8)	(100.0)

Total	19028	6471	17742	7153	50394
	(37.8)	(12.8)	(35.2)	(14.2)	(100.0)

The distribution of race by manner of death (Table 7) shows that homicide was the leading cause of death for Blacks and Coloureds, while the leading cause for Asians and Whites was transport-related deaths. The South African population distribution by race in Figure 5 of Chapter 4 indicated that Blacks are the largest race group, and the rates in Chapter 6 will clearly illustrate the differences in the injury profile by race after adjusting for population size and other explanatory variables. There were 225 (0.4%) deaths with unknown race, mostly for homicide and other unintentional deaths. Numbers are similar to those observed for unknown sex and were excluded from further analysis.

Table 7. Manner of death by race group, 2009

	Homicide N (%)	**Suicide N (%)**	**Transport N (%)**	**Other unintentional N (%)**	**Total N (%)**
Black	16088	4604	14145	5641	40478
	(39.7)	(11.4)	(35.0)	(13.9)	(100.0)
Coloured	1927	579	1268	817	4591
	(42.0)	(12.6)	(27.6)	(17.8)	(100.0)
Asian	316	236	486	125	1164
	(27.2)	(20.3)	(41.8)	(10.8)	(100.0)
White	620	1034	1789	493	3936
	(15.8)	(26.3)	(45.5)	(12.5)	(100.0)
Unknown	77	18	53	77	225
	(34.2)	(8.1)	(23.5)	(34.3)	(100.0)
Total	19028	6471	17742	7153	50394
	(37.8)	(12.8)	(35.2)	(14.2)	(100.0)

A more precise method of determining the inter rater reliability of the data is to assess the level of agreement, between two fieldworkers capturing details on cause-specific mortality from the same folder. This is tested using the Kappa statistic, as described in section 4.2.4 of Chapter 4. The reliability testing of 1 037 records, in which every 20th folder was set aside for re-capture, revealed near perfect agreement

on age (Table 8) and sex (Table 9). The Kappa statistic* was 0.954 (95 percent CI: 0.933-0.975) for age and 0.920 (95 percent CI: 0.889-0.959) for sex (Matzopoulos et al., 2012).

Table 8. Agreement between initial and repeat captures of age

		Repeat								
		Foetus	**<1**	**1-4**	**5-19**	**20-44**	**45-59**	**60+**	**999**	**Total**
Initial	Missing	0	0	0	0	2	0	0	0	2
	Foetus	**20**	0	0	0	0	0	0	0	20
	<1	1	**23**	2	1	0	0	0	2	29
	1-4	0	2	**42**	0	0	1	0	0	45
	5-19	0	1	0	**71**	0	0	0	1	73
	20-44	0	0	0	0	**544**	1	1	0	547
	45-59	0	0	0	0	3	**177**	0	2	182
	60+	0	0	0	1	0	0	**91**	0	92
	999	1	1	0	1	1	0	0	**43**	47
	Total	22	27	44	75	550	179	92	48	1037
	Complete agreement	97.5%								
	Positive disagreement	1.1%								
	Negative disagreement	1.2%								
	Weighted Kappa	**0.954**								

*The Kappa statistic range from -1 to +1, where 1 represents perfect agreement (see section 4.2.4, Chapter 4). *Source: Matzopoulos et al. (2012)*

Table 9. Agreement between initial and repeat captures of sex

		Repeat			
		Male	**Female**	**Unknown**	**Total**
Initial	Missing/ Inconsistent	1	2	0	3
	Male	**766**	12	3	781
	Female	9	**230**	0	239
	Unknown	3	0	**11**	14
	Total	779	244	14	1037
	Complete agreement 97.1%				
	Positive agreement 1.7%				
	Negative agreement 1.2%				
	Weighted Kappa 0.920				

Source: (Matzopoulos et al., 2012)

Table 10 shows that there was also near perfect agreement on apparent manner and cause of death, with a Kappa statistic of 0.860 (95 percent CI: 0.834-0.886).

Table 10. Agreement between initial and repeat captures of apparent manner and cause of death

		Repeat									
		Missing/ Inconsistent	**Homicide**	**Suicide**	**Transport**	**Other Unintentional**	**Undetermined**	**Natural**	**Foetus**	**Undetermined cause**	**Total**
Initial	**Missing/ Inconsistent**	**0**	1	2	0	1	0	0	0	0	4
	Homicide	1	**256**	2	5	3	10	2	0	1	280
	Suicide	0	2	**78**	1	1	4	1	0	1	88
	Transport	0	3	1	**282**	1	4	1	0	0	292
	Other Unintentional	0	3	1	1	**75**	10	2	0	0	92
	Undetermined	1	11	7	1	9	**37**	1	0	8	75
	Natural	0	0	0	0	0	3	**140**	2	2	147
	Foetus	0	0	0	0	0	0	0	**20**	0	20
	Undetermined cause	0	0	2	0	2	7	3	0	**25**	39
	Total	2	276	93	290	92	75	150	22	37	1037

	Complete agreement 88.0%
	Positive disagreement 6.0%
	Negative disagreement 5.4%
	Weighted Kappa 0.860

Source: (Matzopoulos et al., 2012)

5.1.3 Validity: Comparison of national vital registration statistics vs the Injury Mortality Survey

In assessing the third attribute, *validity* of the data, there is no "gold standard" for comparison, as the review of the literature in Chapter 2 revealed substantial data source and coding constraints for injury deaths in South Africa. This is illustrated by Figure 7, which clearly shows the misclassification of injury deaths derived from vital registration data, when compared to the 2009 Injury Mortality Survey's results on the manner of non-natural death. In 2009 Stats SA classified the majority of deaths (63.9%) as other unintentional and only small proportions were attributed to homicide and transport-related deaths. In comparison, the 2009 Injury Mortality Survey estimated that homicide accounted for 36.2% and transport-related deaths for 33.8% of injury deaths nationally. One of the criteria in assessing *validity* (Rao et al., 2005) is the *use of ill-defined categories and codes*. More than 13% of deaths were classified as undetermined in the Stats SA data, in comparison to 4% for the IMS.

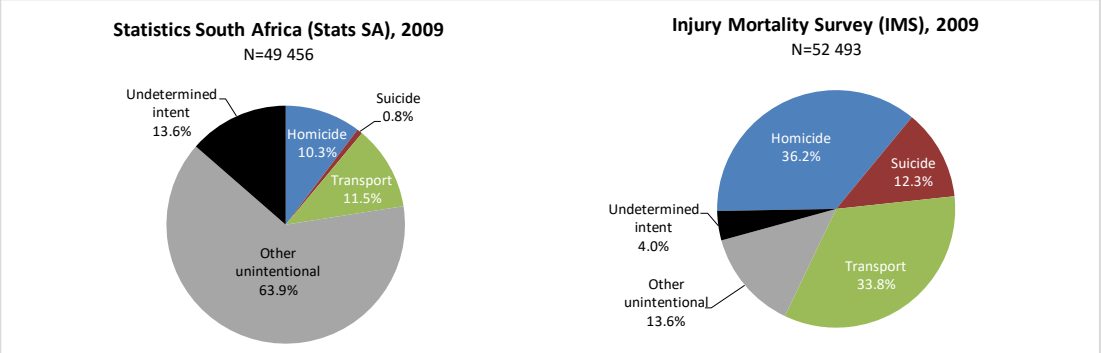

Figure 7. Manner of injury death, Stats SA (Stats SA, 2011) and IMS, 2009 (Matzopoulos et al., 2013)
Source: Prinsloo et al. (2017)

Although the South African Police Service (SAPS) homicide data are considered under-reported, it is the most representative source of national data and a useful source to use in validation of the IMS data (Figure 8). The SAPS data was reported from April 2009 to March 2010 (SAPS, 2014) and reported 13% fewer homicides than the IMS for January to December 2009 (Matzopoulos et al., 2015). The provincial homicide numbers reveal the largest discrepancies are in Gauteng, KwaZulu-Natal and the Northern Cape. Chapter 7 will report on the homicide rates, using the SAPS and IMS data.

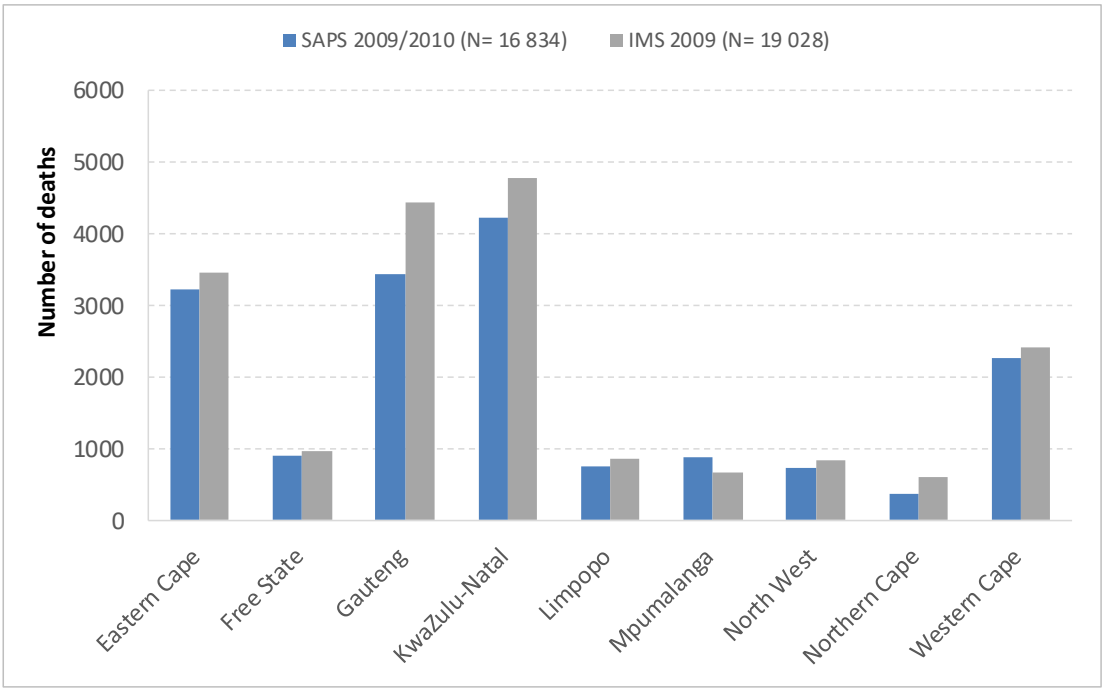

Figure 8. 2009/2010 SAPS number of homicides (SAPS, 2014) versus 2009 IMS number of homicides

Incorrect or improbable age or sex dependency or association is one of the framework criteria to assess the *validity* of the IMS data. As non-natural deaths are not sex-specific, age was used to assess this criterion. The age distribution for each manner of death in Figure 9 highlights the large proportion of homicide, suicide and transport-related deaths from 15-59 years. No unusual age pattern was observed for suicide, which is the only manner of death to likely be age-dependent as an intentional cause of death. The proportion of other unintentional injury deaths peaked for children 1-4 years. Age was unknown for less than 2 percent of suicides and approximately 4% of homicide, transport-related and other unintentional deaths. Unknown age was redistributed for the calculation of rates. The multinomial logistic regression modelling in Chapter 6 and generalized linear modelling in Chapter 7, requires that only a complete and known distribution of the variables be included for analysis. Hence, missing age was excluded from the modelling.

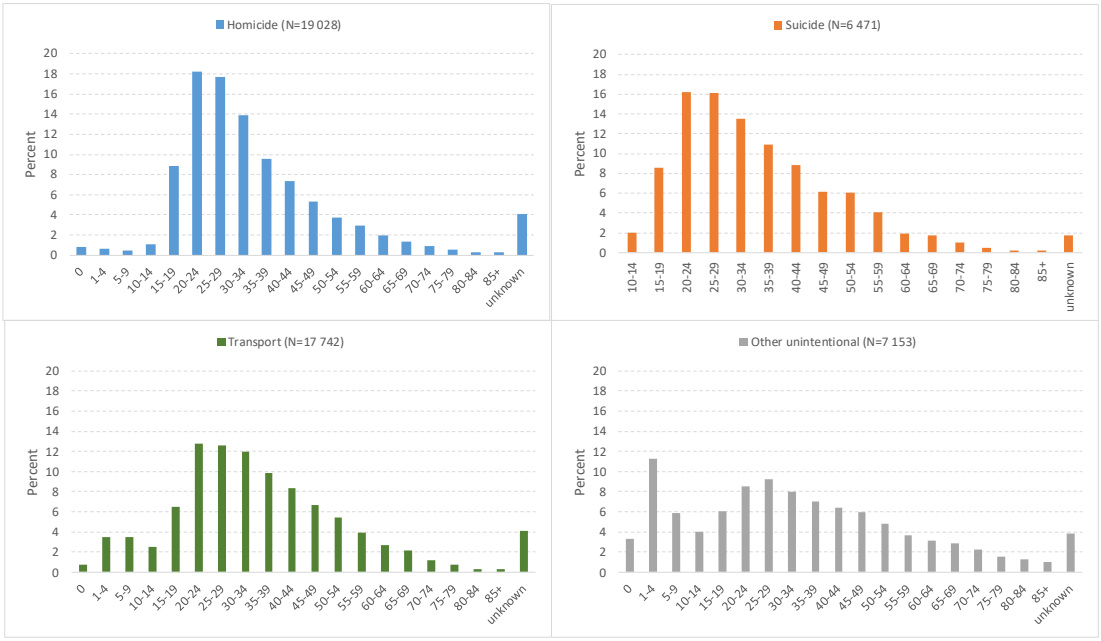

Figure 9. Manner of death by age group, 2009

In summary, the evaluation of the quality of the injury mortality survey data, according to the international framework developed by Rao et al. (2005) in section 5.1 found it to be good in comparison to South African vital registration data. In addition, the data indicate that there are significant proportional differences for injury mortality profiles by metro- and non-metro area. In particular that homicide was higher in metro-areas than non-metro areas, while finding the reverse for transport-related deaths.

5.2 Injury Mortality Rates

The broad description of injury mortality data in the preceding section did not account for the importance of the inclusion of denominator data to provide a measure of risk. Hence, to address Objective 4: *to characterize the variables driving the urban-rural differences of fatal injuries in South Africa*, section 5.2 will take into account the variation in the population structure for metro- and non-metro areas in South Africa by calculating age-standardised rates by sex, race and manner of death for metro- and non-metro areas.

Given the strong age pattern in fatal injuries for 15-44 year olds based on global (WHO, 2002, 2010b, 2014a, 2017a) and South African literature (Norman et al., 2007; Matzopoulos et al., 2015), section 5.2.1 firstly reports on a more in-depth analysis for age through age-specific rates by manner of death for metro- and non-metro areas.

This is followed by age-standardised rates by sex, race and manner of death for metro- and non-metro areas in sections 5.2.2 and 5.2.3.

5.2.1 Metro- and Non-metro difference by Age and Manner of death

Table 11 indicates a significant difference for metro- and non-metro area homicide for the 15-29 year age group, where the homicide rate in metro-areas (73.6; 95%CI: 62.2-84.9) was significantly higher in comparison to non-metro areas (48.8; 95%CI 35.9-61.6). This is investigated further in section 5.2.3, to determine if this significant difference can be attributed to any particular race group.

The other unintentional injury mortality rate was significantly higher in metro areas for 0-4 year olds (27.7 per 100 000; 95%CI: 22.7-32.7) in comparison to non-metro areas (15.6 per 100 000; 95%CI: 11.7-19.6). The other unintentional injury mortality rate for 0-4 year olds in metro areas was among the highest for this manner of death, and the highest rate observed for this age group in comparison to the other manners of death.

Although the other unintentional injury mortality rates for those 80 years and older were significantly different for metro- and non-metro areas, this should be interpreted with caution, as case numbers are low.

Table 11. Age-specific rates for manner of death by metro/non-metro area, 2009

Homicide	Metro	95%CI*	Non-metro	95%CI*	Total	95%CI
0-4	5.5	4.3-6.7	5.3	4.1-6.6	5.4	4.6-6.3
5-14	3.8	2.7-4.9	2.9	1.0-4.8	3.2	1.9-4.5
15-29	73.6	62.2-84.9*	48.8	35.9-61.6*	59.1	51.4-66.9
30-44	70.7	59.7-81.9	52.6	42.0-63.2	61.2	55.6-66.9
45-59	42.1	34.7-49.5	33.7	25.9-41.5	37.5	33.1-41.8
60-69	32.0	24.3-39.7	26.3	19.1-33.4	28.6	24.0-33.2
70-79	21.7	13.5-30.0	23.9	16.4-31.4	23.2	18.1-28.3
80+	24.2	13.9-34.6	22.7	10.4-35.2	23.3	14.5-32.2
Suicide	**Metro**	**95%CI***	**Non-metro**	**95%CI***	**Total**	**95%CI**
0-4	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-0.0
5-14	1.5	1.2-1.8	1.3	0.8-1.9	1.4	1.0-1.8

15-29	19.1	16.2-22.1	17.1	13.1-21.0	18.0	15.7-20.2
30-44	22.6	18.8-26.4	21.5	16.8-26.3	22.1	19.6-24.6
45-59	17.9	13.3-22.6	16.0	12.7-19.2	16.8	14.5-19.2
60-69	10.1	6.8-13.4	11.3	7.7-14.9	10.8	8.4-13.2
70-79	10.8	7.8-13.8	6.7	4.5-8.8	8.1	6.5-9.8
80+	3.7	1.3-6.0	6.2	3.5-8.8	5.3	3.4-7.2
Transport	**Metro**	**95%CI***	**Non-metro**	**95%CI***	**Total**	**95%CI**
0-4	15.9	11.9-20.1	13.5	10.0-16.9	14.3	11.8-16.8
5-14	14.0	11.8-16.2	10.9	8.0-13.8	11.9	10.0-13.9
15-29	37.6	30.4-44.8	40.5	31.1-49.9	39.3	33.7-44.9
30-44	51.1	40.1-62.3	60.7	46.7-74.7	56.1	48.2-64.0
45-59	42.5	34.2-50.7	50.0	39.0-61.1	46.7	40.4-53.0
60-69	40.6	30.7-50.6	39.0	29.1-48.9	39.6	33.4-45.8
70-79	35.1	28.3-41.8	27.1	18.5-35.7	29.9	24.2-35.6
80+	30.9	18.4-43.6	17.2	11.7-22.8	21.9	16.5-27.3
Other Unintentional	**Metro**	**95%CI***	**Non-metro**	**95%CI***	**Total**	**95%CI**
0-4	27.7	22.7-32.7*	15.6	11.7-19.6*	19.8	17.0-22.6
5-14	8.6	6.7-10.6	7.5	5.6-9.4	7.9	6.6-9.2
15-29	12.2	9.9-14.6	11.4	8.9-13.9	11.8	10.3-13.3
30-44	15.4	13.0-17.9	16.5	13.8-19.3	16.0	14.7-17.3
45-59	15.2	12.7-17.7	18.2	14.7-21.6	16.8	15.0-18.7
60-69	22.9	18.1-27.6	17.6	12.5-22.7	19.7	16.5-22.9
70-79	28.7	22.7-34.7	19.8	12.9-26.7	22.9	18.1-27.8
80+	58.3	44.6-71.9*	22.9	16.0-29.8*	34.9	28.5-41.4

*Significant difference between metro and non-metro areas

5.2.2 Age-standardised rates for manner of death by sex and metro/non-metro

The all injury age-standardised mortality rate for metro areas (Table 12) was 1.2 times higher than non-metro areas. The largest variation between metro- and non-metro area was for homicide, with a 1.3 times higher male metro homicide rate (Table 12). For injury mortality overall, the age-standardised homicide rate was highest, followed

closely by transport-related deaths, with substantially lower age-standardised rates for other unintentional injury deaths and suicide.

No significant differences in age-standardised rates were found between metro- and non-metro areas by sex and manner of death. There was a substantial male to female difference, where male mortality rates were 3-6 times higher than females for each manner of death, with the highest male to female ratio for homicide. Transport-related deaths was the only manner of death where the non-metro mortality rate was higher than the metro mortality rate for both males and females. Overall the male injury mortality rate (Total ASR) was significantly higher (181 per 100 000; 95% CI: 161.3-200.7) than females (42.7 per 100 000; 95% CI: 37.1-48.4).

Table 12. Age-standardised rates (ASR) for manner of death by sex and metro/non-metro area, 2009

Manner of death	Metro ASR	95% CI	Non-metro ASR	95% CI	Total ASR	95% CI
Homicide	**45.1**	**37.7-52.5**	**33.2**	**25.2-41.1**	**38.4**	**33.8-43.0**
Male	78.3	65.2-91.4	58.5	43.9-73.1	67.4	58.9-75.8
Female	12.1	9.3-15.0	10.6	7.8-13.4	11.3	9.5-13.0
Suicide	**14.0**	**11.3-16.8**	**12.9**	**9.9-15.9**	**13.4**	**11.6-15.2**
Male	23.3	18.4-28.1	23.2	17.6-28.8	23.2	19.9-26.5
Female	5.0	3.8-6.2	4.1	2.7-5.6	4.5	3.5-5.4
Transport	**36.2**	**28.9-43.5**	**38.7**	**29.8-47.6**	**37.4**	**32.1-42.7**
Male	57.5	45.8-69.2	62.1	48.0-76.1	59.6	51.3-67.9
Female	15.7	11.7-19.7	18.5	13.3-23.6	17.2	14.1-20.4
Other Unintentional	**16.7**	**13.6-19.7**	**14.6**	**11.4-17.8**	**15.3**	**13.3-17.2**
Male	23.9	18.9-28.9	23.4	18.2-28.6	23.3	20.2-26.5
Female	9.6	7.4-11.7	7.0	5.0-9.1	7.9	6.5-9.3
All injuries	**118.5**	**99.0-138.1**	**102.5**	**81.8-123.3**	**109.0**	**97.1-121.0**
Male	193.3	161.5-225.2	172.5	137.6-207.4	181.0	161.3-200.7
Female	45.2	36.7-53.8	41.4	32.0-50.9	42.7	37.1-48.4

5.2.3 Age-standardised rates for race by metro/non-metro and manner of death

Table 13 shows that it is only among Blacks that the metro homicide rate (52.6 per 100 000; CI: 44.6-60.5) was significantly higher than non-metro areas (33.8 per

100 000; CI: 24.6-43.0). Coloureds had a higher but not significant homicide rate for metro compared with non-metro , but the non-metro homicide rate (40.2 per 100 000; CI: 22.0-58.6) was higher than that for Blacks. The homicide rate for Asians was higher in non-metro areas (30.8 per 100 000; CI: 15.1-47.9), while Whites had a similar homicide rate for metro (11.3 per 100 000, CI: 6.7-15.9) and non-metro areas (11.6 per 100 000; CI: 6.5-16.7).

The age-standardised suicide rate was highest for Whites, in non-metro areas (23.5 per 100 000; CI: 15.1-31.8). Blacks had the highest age standardised transport mortality rate, followed closely by Whites, who had the highest rate for non-metro areas (59.6 per 100 000; 95%CI: 38.5-80.6). This was significantly different from Whites in metro-areas (26.5 per 100 000; 95%CI: 16.4-36.6). The Asian transport mortality rate was also higher in non-metro areas (57.3 per 100 000; 95%CI: 27.5-87.9) and similar to Whites. The other unintentional injury mortality rate was highest for Coloureds, in non-metro areas. Figure II of Appendix III shows the injury mortality rates by age and race for each manner of death.

Table 13. Age-standardised rates (ASR) for manner of death by race and metro/non-metro area, 2009

Homicide	**Metro ASR**	**95% CI***	**Non-metro ASR**	**95% CI***	**Total ASR**	**95% CI**
Black	52.6	44.6-60.5*	33.8	24.6-43.0*	41.2	35.6-46.9
Coloured	45.3	26.8-63.7	40.2	22.0-58.6	42.9	29.9-55.9
Asian	22.0	14.5-29.6	30.8	15.1-47.9	24.0	16.8-31.2
White	11.3	6.7-15.9	11.6	6.5-16.7	11.4	8.0-14.8
Suicide	**Metro ASR**	**95% CI***	**Non-metro ASR**	**95% CI***	**Total ASR**	**95% CI**
Black	11.9	9.2-14.6	11.8	8.4-15.2	11.9	9.7-14.1
Coloured	13.0	9.6-16.3	12.6	7.9-17.2	12.8	9.9-15.6
Asian	17.7	7.6-27.8	17.4	2.1-33.4	17.6	8.7-26.4
White	19.0	11.7-26.3	23.5	15.1-31.8	20.5	15.2-25.9
Transport	**Metro ASR**	**95% CI***	**Non-metro ASR**	**95% CI***	**Total ASR**	**95% CI**
Black	41.6	32.3-51.0	37.8	27.9-47.6	38.6	32.2-45.1

Coloured	28.6	20.6-36.6	30.4	21.8-58.1	29.5	23.9-35.0
Asian	31.6	20.1-43.0	57.3	27.5-87.9	37.2	25.8-48.7
White	26.5	16.4-36.6*	59.6	38.5-80.6*	38.2	28.6-47.7
Other Unintentional	**Metro ASR**	**95% CI***	**Non-metro ASR**	**95% CI***	**Total ASR**	**95% CI**
Black	18.5	14.1-22.9	14.0	10.2-17.7	15.3	12.8-17.9
Coloured	16.6	13.0-20.1	23.0	17.8-28.7	19.7	16.3-23.2
Asian	10.9	3.9-18.0	6.9	0.0-15.0	10.1	4.0-16.2
White	9.3	6.3-12.2	10.3	5.4-15.2	9.6	7.0-12.2
All injuries	**Metro ASR**	**95% CI***	**Non-metro ASR**	**95% CI***	**Total ASR**	**95% CI**
Black	132.8	109.2-156.4	100.6	76.7-124.4	112.1	97.1-127.0
Coloured	105.5	76.0-135.0	107.6	75.4-139.9	106.5	84.9-128.1
Asian	86.5	54.9-118.0	115.0	58.5-172.2	92.8	65.4-120.2
White	69.9	46.6-93.1	108.0	74.9-141.0	83.3	65.4-101.1

*Significant difference between metro and non-metro areas

The all-injury mortality rate in Table 13 appears to be driven by the high rates for Blacks, which was significantly higher in metro-areas in comparison to non-metro areas. It is also driven by the high transport mortality rates for Asians and Whites in non-metro areas.

In summary, significantly higher metro-area mortality rates were found for homicide in the 15-29 year age group and for other unintentional injury deaths in the 0-4 year age group. The age-standardised homicide rate for Blacks in metro-areas was significantly higher than non-metro-areas. Homicide was highest for Coloureds as a result of the high rates in non-metro areas, followed closely by Blacks. Transport-related deaths ranked second to homicide and were highest for Blacks, followed closely by Whites who had a significantly higher transport-related mortality rate in non-metro areas in comparison to metro areas. The other unintentional injury mortality

rate was 2.4 and 2.5 times lower than transport-related deaths and homicide respectively, and highest for Coloureds followed by Blacks. The suicide rate was lowest of all the injury deaths and was highest for Whites, followed by Asians. No significant metro/non-metro differences were found by sex but the largest difference was for male homicide.

5.3 Discussion

5.3.1 Data quality

This section summarizes and discusses the findings according to Rao et al's (2005) data quality framework utilized for this Chapter. In assessing the *generalizability/representativeness* of the survey data and its *coverage*, this is the first South African injury mortality study to have full representation of urban and rural areas through its sampling of metro- and non-metro area mortuaries (Matzopoulos et al., 2015). The *completeness* criterion under the dimension of *generalizability/ representativeness* was satisfied, as only 2 099 (4%) of the estimated 52 493 deaths had an undetermined manner of death in comparison to the 13.5% reported by Stats SA for 2009 (Stats SA, 2011).

Although an assessment of the quality of global mortality data by Bhalla et al. (2010) regarded fewer than 20% of deaths classified as undetermined to be of good quality, it was based on death registration from vital statistics. It is expected that a survey based on post-mortem folders would have fewer undetermined deaths, as more information would be available to the data collectors. Countries with similar proportions of undetermined deaths as South Africa's vital registration include Russia (15%) and the United Kingdom (12%), but Russia has a higher magnitude of undetermined deaths, with an age-standardised non-natural death rate that is 8.5 times higher in comparison to the United Kingdom (Andreev, Shkolnikov, Pridemore, & Nikitina, 2015).

An assessment of the *reliability* of the survey data revealed near perfect agreement (Kappa statistic= 0.80 and above) (Cohen, 1968) on age and sex (weighted Kappa= 0.95 and 0.92 respectively) and similarly for apparent manner and cause of death (weighted Kappa= 0.86). The *consistency of cause patterns* for sex as a further

assessment of the *reliability* of the data compares to the findings of the National Injury Mortality Surveillance System (NIMSS) for cities between 2001-2005 (Matzopoulos, 2005; Prinsloo, 2007); and later NIMSS studies that included rural area mortuaries (Donson, 2008), where approximately 80% of non-natural deaths were males.

The finding that males had a higher proportion of homicide, while females had a higher proportion of transport-related deaths is also in line with the trend of *cause patterns* for the NIMSS (Matzopoulos, 2005; Prinsloo, 2007; Donson, 2008) and National Burden of Disease study estimates (Norman et al., 2007; Msemburi et al., 2016; Pillay-van Wyk et al., 2016a). The *cause patterns* by race was not reported in earlier NIMSS studies, but separate analysis of the NIMSS data in five urban-biased cities reported a higher risk for homicide among Blacks (Matzopoulos, 2012). An analysis of Cape Town homicide trends reported the risk for homicide among Blacks to be 10 times higher compared to Whites, and the risk for Coloureds to be 5.4 times higher compared to Whites (Matzopoulos et al., 2018). The current findings in this Chapter, where Blacks and Coloureds have a higher proportion of homicide, while Asians and Whites have a higher proportion of transport-related deaths will be explored in Chapter 6 and Chapter 7 to test for any significant associations.

An assessment of the *validity* of the survey data showed that the Stats SA injury deaths are grossly misclassified, as described in Chapter 2 and shown in Figure 7 of this chapter. Detail on the specific manner of injury death revealed substantially lower proportions of homicide, suicide and transport-related deaths reported by Stats SA (Stats SA, 2011), in comparison to the IMS (Prinsloo et al., 2017). From 2007 onward, application of the automated ICD-10 coding rule for vital registration data resulted in 89-99% of gunshot deaths reported as other unintentional (Matzopoulos et al., 2016).

The Stats SA and IMS comparison by manner of death indicates that empirical data from mortuary surveys provide greater completeness of information than vital registration. Current vital registration data on injury deaths cannot be used to monitor progress on achieving the Sustainable Development Goals to reduce violence by 2030. A review and amendment of the Inquest Act of 1959 (Inquests Act 58, 1959), which prohibits forensic pathologists from declaring the actual manner of death, will take years. The forensic pathologists should therefore be allowed to declare an apparent

manner of death on the death notification form (DHA-1663) (Prinsloo et al., 2017). In a further assessment of the *content validity* of the homicide data, the crude comparison between the number of homicides per province for the IMS and SAPS showed that the two data sources are comparable, despite a few provincial discrepancies, and will be explored further in the homicide rates analysis of Chapter 8.

An assessment of *incorrect or improbable age-dependency* in Figure 9 of this chapter indicates that proportionally the highest incidence for each manner of death was among those 15-59 years. Transport-related and other unintentional injury deaths were more randomly spread across age groups and was also high in the 1-4 and 5-9 year age groups, with no indication of improbable age for suicide. The 2nd NBD study also found that interpersonal violence and road injuries were among the ten leading causes of death for the 15-44 year age group; as were road injuries for children under 5 and 10-14 years. Other unintentional injury deaths such as drowning and burns also featured among the 10 leading causes of death for children 10-14 years (Msemburi et al., 2016).

To complete the evaluation of the data according to the framework of Rao et al. (2005), the final attribute: *policy relevance* of the data is assessed using two criteria: *timeliness*, which refers to outdated cause-of-death data that can lose their relevance for policy formulation and *geographical disaggregation*, which refers to population-based health statistics that are essential for targeted interventions and policy formulation.

In assessing the *timeliness* of the 2009 IMS data, on which the findings of this thesis are based, there has been no similar nationally representative study on injury deaths since 2011 when the IMS was conducted. The burden of disease estimates for injury deaths indicate that even though homicide decreased substantially between 1997 and 2009, the rates have been relatively constant since 2011 at approximately 35 per 100 000 (Msemburi et al., 2016). There has not been any substantial change in the homicide rates when comparing the 2009 IMS (38.4 per 100 000 population) with the 2016/2017 homicide rate reported by SAPS (34.1 per 100 000) (SAPS, 2017b).

The burden of disease estimates for road traffic deaths, suicide and other unintentional injury deaths between 1997 and 2012 indicate that trends remained relatively constant for these injury deaths (Msemburi et al., 2016; Pillay-van Wyk et al., 2016a, 2016b). The 2009/2010 SAPS homicide data and RTMC road traffic mortality data were under-reported in comparison to the IMS (Matzopoulos et al., 2015). A validation with Stats SA data found that mortuary data is a more reliable source of information (Prinsloo et al., 2017). Validation of the IMS suicide and other unintentional injury deaths were not possible, due to the absence of reliable national data for these manners of death.

In assessing the *geographical disaggregation* of the data, the IMS was the first nationally representative study on injuries and the first to include metro- and non-metro areas. The framework discussed by Rao et al. (2005) indicates that population-based health statistics are essential for targeted intervention strategies and policy development.

5.3.2 Metro-/Non-metro differences

The higher proportion of homicide and lower proportion of transport injuries experienced in metro areas compared with non-metro areas needs to be explored in detail in Chapter 6. A more sophisticated approach -multinomial logistic regression, will be used to assess whether the population characteristics (age, sex and race) account for the differences, by testing Hypothesis 1: *Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas.*

The findings that appear to have the most substantial influence on the metro/non-metro difference for injuries are the significantly higher homicide rates for Blacks in metro areas in comparison to non-metro areas and the high homicide rates for Coloureds in metro areas, in comparison to the other race groups. There are other significant differences in the age-standardised rates for homicide which will be explored in more detail in Chapter 7, along with particular hypotheses as set out in Chapter 3 (Aims and Objectives) using generalized linear modelling. In addition, the significantly higher age-standardised transport-related mortality rates for Whites in non-metro areas compared to Whites in metro areas, and the exceptionally high rates

for Asian transport-related deaths in non-metro areas all influence the national injury mortality profile.

The next section discusses the factors that may contribute to the large metro/non-metro difference for transport-related deaths. Chapter 6 will investigate the metro/non-metro proportional differences for injury mortality noted in this chapter in greater detail, while Chapter 7 will focus on homicide only to discuss the contribution of homicide to the metro/non-metro differences for injury mortality. The policy relevance of these findings will be discussed in the Conclusion (Chapter 8).

5.3.3 Metro-/non-metro differences of transport-related deaths

Although the metro/non-metro age-standardised transport-related mortality rates were similar, it was exceptionally high for males compared to females. The significantly higher transport-related mortality rate for Whites in non-metro areas in comparison to metro areas is of concern. The non-metro transport-related mortality rate was also considerably higher than metro areas for Asians. It is possible that some of the transport-related deaths in non-metro or rural areas were urban residents driving through rural areas, especially during the Christmas vacation period (Ngcobo, 2017). This is supported by the IMS data for 2009, which showed that 1 181 (11.4%) transport-related deaths occurred in non-metro areas during December, as opposed to an average of 837 deaths (8.1%) for January to November. One fifth of those December deaths occurred over only three days, between 24 to 26 December. The metro areas had no major peaks during the year for transport-related deaths.

One of the factors that could explain the higher transport-related mortality rates in non-metro/rural areas include the high speed differential at the point of collision between urban (60km/h speed limit) and rural areas (120km/h speed limit on national roads), where the impact and injury is more severe at a higher speed. Besides speeding over long-distances, other factors include risky overtaking behaviour, emergency medical services' response times, long distances to hospital care, the unavailability of specialist practitioners (Maio et al., 1992; Weiss et al., 2001; Clark, 2003; Peek-Asa et al., 2004) and the fact that crashes tend to be more severe on rural roads (Maio et al., 1992). Non-adherence to traffic laws such as speed limits, seatbelts and alcohol consumption limits and poorly enforced traffic laws (Peek-Asa et al., 2004; Zwerling et al., 2005) all lead to higher transport-related mortality rates.

These factors could also play a role in urban-area transport-related deaths, but the rates in rural areas are known to be higher for the aforementioned reasons (Maio et al., 1992; Peek-Asa et al., 2004; Zwerling et al., 2005; Mitchell & Chong, 2010; Burrows, Auger, Gamache, & Hamel, 2013; Myers et al., 2013; Raatiniemi et al., 2016).

The next chapter, Chapter 6 will explore the proportional metro- and non-metro differences noted for the injury mortality profile in this chapter in greater detail, by:

a) Illustrating via multiple correspondence analysis, the relationships between categories of explanatory variables, i.e. age, sex, race, manner of death and metro-/non-metro area to select candidate variables for inclusion in the multinomial logistic regression analysis.

b) Multinomial logistic regression to look at adjusted associations of explanatory variables (i.e. age, sex, race and metro-/non-metro area) for homicide, suicide and transport-related deaths, relative to other unintentional injury deaths as the reference outcome.

6 FACTORS ASSOCIATED WITH INJURY MORTALITY PROFILES: CORRESPONDENCE ANALYSIS AND MULTINOMIAL MODELLING

Chapter 5 provided a basic presentation of the Injury Mortality Survey (IMS) data and a crude comparison of numbers and proportions for available injury mortality data sources, to assess the IMS data quality, utilizing the framework developed by Rao et al. (2005). In addition, it provided a basic analysis of injury deaths and an analysis of age-specific and age-standardised rates for each manner of death by metro- and non-metro area. The chapter concluded that the assessment of the generalizability/representativeness, reliability, validity and policy relevance of the data found that in South Africa, injury mortality surveys provide greater completeness of information than deaths reported through vital registration. The basic analysis of the proportions in Chapter 5 found that there are differences in the injury mortality profiles for metro and non-metro areas. This was also noted for other countries in the literature review of this thesis.

Hence, Chapter 6 needs to explore this further by addressing Objective 4: *to characterize the variables driving the urban-rural differences of fatal injuries in South Africa.* This will be done by assessing how the metro/non-metro profiles are affected by age, sex and race, by testing Hypothesis 1:

Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas.

The multiple correspondence analysis in section 6.1 is used to further investigate the known associations between the manner of death by age, sex, race and metro/non-metro already noted in Chapter 5 in order to identify the explanatory variables for inclusion in the multinomial logistic regression modelling, to evaluate the statistical significance of the associations (section 6.2).

6.1 Multiple Correspondence Analysis (MCA)

As discussed in section 4.3.2 of the Methods chapter, MCA is particularly useful for data exploration of outcome variables of interest which have multiple categories, and the relationship of all these to other explanatory variables. This section provides an

innovative approach to variable selection, in the form of a graphical illustration of the relationships or associations between the variables, with the additional benefit of showing the response categories for each variable. For example, a variable such as manner of death will have the following response categories: homicide, suicide, transport and other unintentional injury deaths. In addition, the variable response categories for age, sex, race and metro/non-metro will also be included in the MCA for this chapter.

MCA locates all the variables in a Euclidean space. The two dimensions of this space are plotted to examine the category associations, usually in a form of clustering. The percentage variance on the two dimensions is an indication of the variance explained by visualization of the data. The higher the value, the fewer insights are likely to be missed by the visualization. The zero intersection on the horizontal and vertical axis of the graph is known as the origin. Response categories furthest from the origin are more distinct than response categories closer to the origin.

6.1.1 MCA of manner of death, age, sex, race and metro/non-metro

Figure 10 shows that other unintentional injuries are most distinctly associated with childhood. Black and Coloured male homicide, and youths aged 15-29 years are associated. Asians and suicide are associated and there is a distinct association for Whites, females, and transport-related deaths in the 45-59 year and 60+ age group. Metro/non-metro are both close to the origin, as are males and the 30-44 year age group and cannot be associated solely with any particular manner of death at this point of the analysis. The two dimensions illustrated explains only 22.6% of the percentage variance in the data. Hence, the visualization does not provide enough insight to the likely associations between variable response categories. Further exploratory analysis of the MCA found that, the more variables were added to the model, the lower the percentage variance (data not shown).

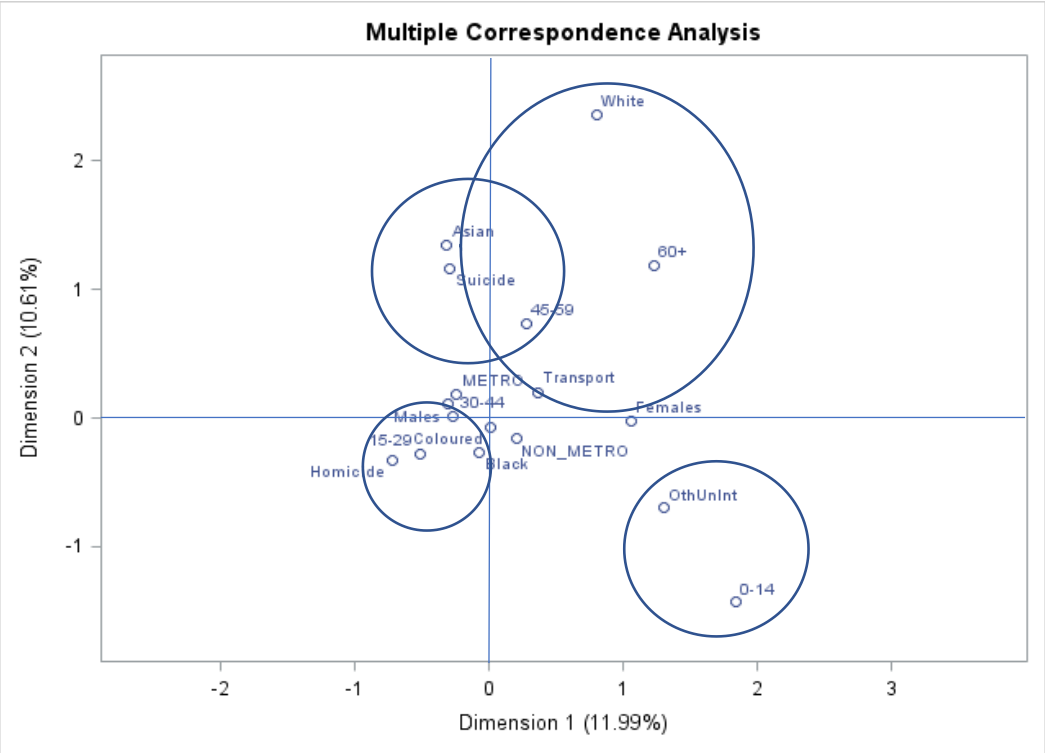

Figure 10. Manner, age, sex, race and metro/non-metro

In summary, the MCA confirms the existence of particular proportional differences between manner of death and the other variables (age, sex, race, metro- and non-metro areas). The most distinct associations noted were that for other unintentional injury deaths for 0-14 years and for Whites aged 60+ years, as they were furthest from the origin. The 30-44 year age group and males were plotted nearest to the origin, indicating that this is the average profile seen within the data. This corresponds to the findings in Chapter 5, which indicated that the majority of non-natural deaths were males, with a high proportion in the 30-44 year age group.

The association with Black and Coloured homicide also relates to the high proportions observed in Chapter 5, as do the association with transport-related deaths for the older middle-aged. The association of suicide with Asians was contrary to expectation, as a higher proportion of transport-related deaths were noted in Chapter 5. This may be attributed to the low percentage variance (22.6%), indicating that this visualization could not provide enough insight to the probable associations within the data, and that the MCA cannot solely be relied upon to identify associations within the data.

As the MCA does not indicate statistical significance and cannot be used for inference, it was conducted for exploratory purposes to provide an indication of the likely associations and related variables to include in the multinomial logistic regression analysis for section 6.2 of this chapter. The low percentage variance indicates that it is possible that new associations could be identified through the multinomial logistic regression analysis. The associations to be tested from the MCA include:

1) Females are associated with transport-related deaths, while males are associated with homicide
2) Children 0-14 years and other unintentional injury deaths are associated
3) Asians and suicide, 45-59 years are associated
4) Whites, 45-59 years and 60+ years are associated with transport-related deaths
5) Black and Coloured males, 15-29 years are associated with homicide

6.2 Multinomial logistic regression analysis (MLR)

This section will further analyse the five associations noted by the MCA. No distinct associations for metro- and non-metro deaths were noted with the MCA analysis. Metro-/Non-metro will be included in the MLR analysis, to address objective 4: *to characterize the variables driving the urban-rural differences of fatal injuries in South Africa,* and to test Hypothesis 1:

Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas.

Multinomial logistic regression analysis (Hardin & Hilbe, 2007) is used to model the associations between independent variables and the outcome proportions. It will be used to address Hypothesis 1 and to identify which of the observed associations in the preceding MCA are significant. This analysis is a more sophisticated, refined approach to MCA, as it simultaneously adjusts for age, race, sex and metro/non-metro to provide the relative risk ratios (RRR) and the level of significance to confirm the likely associations with the manner of death, particularly with regard to metro/non-metro differences. It provides a logistic regression analysis for multiple outcomes at

the same time. In addition, it will identify which of the significant associations noted have most relevance to inform public health policy.

Table 14 indicates the proportion of deaths i.e. for males and females; and by race, age and metro-/non-metro for each manner of death separately. Multinomial logistic regression estimates the relative risk ratio (Table 17) for each of these characteristics against a reference category within each manner of death relative to the risk among the reference outcome. Death as a result of other unintentional injury was selected as the reference outcome with females, 45-59 years, Whites and non-metro areas as reference categories, for ease of interpretation of the high-risk categories, while still ensuring stable parameter estimates. The basis for the modelling and the selected explanatory variables arose from the literature review, which identified the high-risk categories for injury deaths, the leading injury mortality profiles, the likely interaction terms and the metro/non-metro differences for injury deaths.

Table 14. Proportions by manner of death

	Homicide %	Suicide %	Transport %	Other unintentional %	All injuries
Male	85.6	82.1	76.1	72.5	79.9
Female	14.4	17.9	23.9	27.5	20.1
	100.0	100.0	100.0	100.0	100.0
Black	84.9	71.4	80.0	79.7	80.7
Coloured	10.2	9.0	7.2	11.5	9.2
Asian	1.6	3.6	2.7	1.8	2.3
White	3.3	16.0	10.1	7.0	7.8
	100.0	100.0	100.0	100.0	100.0
0-14	3.1	2.0	10.7	25.5	8.8
15-29	46.8	41.7	33.3	24.7	38.3
30-44	32.1	34.0	31.5	22.3	30.7
45-59	12.6	16.6	16.8	15.0	14.9
60+	5.5	5.7	7.7	12.4	7.3
	100.0	100.0	100.0	100.0	100.0

Metro	51.7	46.1	41.2	44.1	46.2
Non-metro	48.3	53.9	58.8	55.9	53.8
	100.0	100.0	100.0	100.0	100.0

The intrinsic value or utility of the multinomial logistic regression, which is to identify significant interaction terms between the variables of interest and the fact that the modelling relates to the proportions of injury mortality (in the likely absence of denominator data), were highlighted in Chapter 4 (Methods).

The study design was a survey and the survey structure or sampling frame of the data (Table 3 in the Methods chapter) had to be accounted for in the analysis. Hence, the survey set command in Stata was used to consider the survey design. Analysis weights, as described in section 4.2.6 of Chapter 4 were used. Relative risk ratios for the explanatory variables and interaction terms, p-values and 95% confidence intervals are presented in the model. The MLR model output reflects the relative risk ratios from the model for a particular outcome, in contrast to the reference outcome, thus ignoring the other outcomes. This makes the model output results difficult to interpret directly, particularly when interaction terms are included.

Hence, for the models with interaction terms, predicted proportions are calculated and illustrated in graphical form, for ease of interpretation of the model's findings. The modelling approach initially explored homicide, suicide, transport-related and other unintentional injury deaths as reference outcome (data not shown), but the predicted proportions remained the same throughout. Thus, other unintentional was selected as the reference outcome, on the basis that it was similar for metro- and non-metro areas, allowing for a better understanding of the contributors to metro/non-metro for the remaining manners of death.

The first MLR model included a base model fitted with age, sex, race and metro/non-metro as independent variables associated with manner of death (Table 15).

Table 15. Multinomial logistic regression Model 1 (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	p-value	95% Confidence Interval		RRR	p-value	95% Confidence Interval		RRR	p-value	95% Confidence Interval	
Metro/Non-metro												
Non-metro (ref)	1.00				1.00				1.00			
Metro	1.31	0.003	1.10	1.56	0.97	0.652	0.85	1.11	0.84	0.028	0.72	0.98
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.64	<0.001	1.51	1.77	1.32	<0.001	1.15	1.51	0.99	0.887	0.92	1.07
Race												
White (ref)	1.00				1.00				1.00			
Coloured	1.62	<0.001	1.30	2.01	0.29	<0.001	0.24	0.34	0.38	<0.001	0.31	0.46
Asian	1.56	0.010	1.12	2.17	0.73	0.111	0.50	1.08	0.96	0.726	0.74	1.24
Black	2.00	<0.001	1.73	2.31	0.34	<0.001	0.28	0.41	0.61	<0.001	0.54	0.70
Age group												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.15	<0.001	0.12	0.18	0.09	<0.001	0.07	0.11	0.39	<0.001	0.35	0.43
15-29	2.12	<0.001	1.92	2.34	1.70	<0.001	1.48	1.95	1.25	<0.001	1.13	1.37
30-44	1.62	<0.001	1.51	1.74	1.49	<0.001	1.35	1.65	1.31	<0.001	1.22	1.41
60+	0.59	<0.001	0.52	0.66	0.37	<0.001	0.30	0.45	0.51	<0.001	0.46	0.57
_cons	0.72	0.002	0.60	0.88	2.01	<0.001	1.59	2.54	4.76	<0.001	3.93	5.77

Relative to other unintentional injury deaths, Model 1 (Table 15) indicated a significantly higher likelihood for homicide in metro areas (RRR=1.31 p=0.003), compared to non-metro areas. It indicated no difference between metro- and non-metro areas for suicide, while the likelihood of a transport-related death was significantly lower in metro areas (RRR=0.84; p=0.028) than non-metro areas. This supports Hypothesis 1: *Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas.*

Thereafter, a series of models were fitted based on a review of the injury mortality profile literature, with different pairwise interaction terms, mostly with metro/non-metro (Models 2-8 as Tables IV-XI in Appendix III and Table 16) to explore in detail the associations identified by the MCA. The predicted proportions of the models are reflected in Figure IV-Figure XIV in Appendix III. Model 7, with a race*age and race*M/NM interaction term was selected as the most influential metro/non-metro model that best fits the data based on the BIC, Pseudo R^2 and log likelihood (Table 16).

Table 16. Multinomial logistic regression model fit statistics

Model (interactions)	Log likelihood	DFs	LR Chi^2	p-value	Pseudo R^2	AIC	BIC
Model 1 (M1): sex, race, age, Metro/Non-metro (M/NM)	-27086.6	27	3343.1	<0.001	0.058	54233.2	54473.7
Model 2: M1, race*M/NM	-27055.4	36	3405.5	<0.001	0.059	54188.8	54501.4
Model 3: M1, sex*M/NM	-27075.1	30	3366.0	<0.001	0.059	54216.3	54480.8
Model 4: M1, race*M/NM, sex*M/NM	-27044.1	39	3428.2	<0.001	0.060	54172.1	54508.8
Model 5: M1, sex*race	-27065.4	36	3385.4	<0.001	0.059	54208.9	54521.5
Model 6: M1, race*age	-26924.4	63	3667.6	<0.001	0.064	53980.7	54509.8
Model 7: M1, race*age, race*M/NM	-26892.2	72	3731.9	<0.001	0.065	53934.4	54535.6
Model 8: M1, age*M/NM	-27069.1	39	3378.2	<0.001	0.059	54222.1	54558.8

Table 17 presents the estimates from the MLR in Model 7. For ease of interpretation, the predicted proportions of the model were calculated for all manners of death when adjusting for age, sex, race and metro/non-metro based on Model 7. Figure 11 shows the predicted proportions for each manner of death by sex and, Figure 12 shows the predicted proportions for manner of death by race and age group and Figure 13 for manner of death by race and metro/non-metro.

Table 17. Multinomial logistic regression Model 7 (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.64	<0.001	1.52	1.77	1.33	<0.001	1.16	1.52	1.00	0.921	0.92	1.08
Race												
White (ref)	1.00				1.00				1.00			
Coloured	0.51	0.005	0.32	0.81	0.13	<0.001	0.08	0.20	0.20	<0.001	0.15	0.28
Asian	1.32	0.501	0.58	3.03	0.51	0.174	0.20	1.36	0.66	0.221	0.34	1.29
Black	0.88	0.473	0.60	1.27	0.21	<0.001	0.15	0.30	0.54	<0.001	0.39	0.73
Age group												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.04	<0.001	0.02	0.09	0.03	<0.001	0.01	0.06	0.31	<0.001	0.17	0.56
15-29	0.44	0.001	0.28	0.70	0.94	0.733	0.68	1.32	2.67	<0.001	1.91	3.73
30-44	0.49	0.007	0.29	0.82	1.02	0.928	0.71	1.45	1.36	0.060	0.99	1.87
60+	0.42	<0.001	0.29	0.62	0.21	<0.001	0.16	0.28	0.33	<0.001	0.25	0.42
race*age												
W 45-59 (ref)	1.00				1.00				1.00			
C 0-14	5.79	<0.001	2.70	12.40	2.90	0.016	1.23	6.84	2.10	0.026	1.10	4.01
C 15-29	6.42	<0.001	3.85	10.68	2.19	0.003	1.31	3.65	0.58	0.003	0.41	0.83
C 30-44	4.15	<0.001	2.42	7.12	1.58	0.048	1.01	2.48	0.96	0.819	0.67	1.38
C 60+	1.11	0.587	0.75	1.66	1.04	0.875	0.61	1.78	2.20	<0.001	1.56	3.09
A 0-14	5.45	0.003	1.81	16.39	5.77	<0.001	2.39	13.97	2.31	0.016	1.18	4.52
A 15-29	7.42	<0.001	2.76	19.93	3.18	0.044	1.03	9.80	2.47	0.055	0.98	6.23
A 30-44	5.20	<0.001	2.37	11.40	2.14	0.025	1.10	4.14	2.29	0.001	1.41	3.70
A 60+	2.77	0.111	0.79	9.76	3.57	0.026	1.17	10.91	5.82	<0.001	3.43	9.88
B 0-14	3.30	0.002	1.55	7.02	3.38	0.003	1.56	7.32	1.13	0.687	0.61	2.09

B15-29	4.87	<0.001	3.14	7.54	2.02	<0.001	1.52	2.69	0.39	<0.001	0.28	0.55
B 30-44	3.47	<0.001	1.99	6.05	1.60	0.018	1.09	2.35	0.91	0.586	0.63	1.30
B 60+	1.38	0.146	0.89	2.12	2.04	<0.001	1.42	2.92	1.67	<0.001	1.29	2.17
M/NM												
Non-metro (ref)	1.00				1.00				1.00			
Metro	1.18	0.302	0.86	1.61	0.99	0.926	0.76	1.28	0.51	<0.001	0.40	0.64
race*M/NM												
W Non-metro (ref)	1.00				1.00				1.00			
C Metro	1.52	0.139	0.87	2.67	1.72	0.004	1.20	2.48	2.84	<0.001	1.95	4.13
A Metro	0.34	0.004	0.16	0.70	0.61	0.284	0.25	1.52	0.61	0.130	0.32	1.16
B Metro	1.10	0.572	0.79	1.52	0.87	0.385	0.64	1.19	1.66	<0.001	1.28	2.16
_cons	1.61	0.009	1.13	2.30	3.08	<0.001	2.29	4.13	5.91	<0.001	4.42	7.90

RRR: Relative Risk Ratio IRRR[#] : Interaction's Relative Risk Ratio for interactions of race*age -calculated as RRR(race)*RRR(age)*RRR(Race*age) and race*M/NM

[*]p-value: <0.05 denotes statistical significance [**] L CI: Lower Confidence Interval U CI: Upper Confidence Interval

Compared with other manners of death, a female's risk of dying is much lower for homicide at 14% (Table 14). The MLR model 7 (Table 17) indicates that relative to other unintentional, males had a significantly higher relative risk ratio than females for homicide (RRR=1.64; p<0.001) and suicide (RRR=1.33; p<0.001), while there was no difference between males and females for transport-related deaths. The predicted proportions in Figure 11 also confirm that transport-related deaths, followed by homicide was the leading manners of death for females, while for males it was homicide followed by transport-related deaths. This confirms association 1 and the differences observed *by sex for homicide and transport-related deaths* in the multiple correspondence analysis.

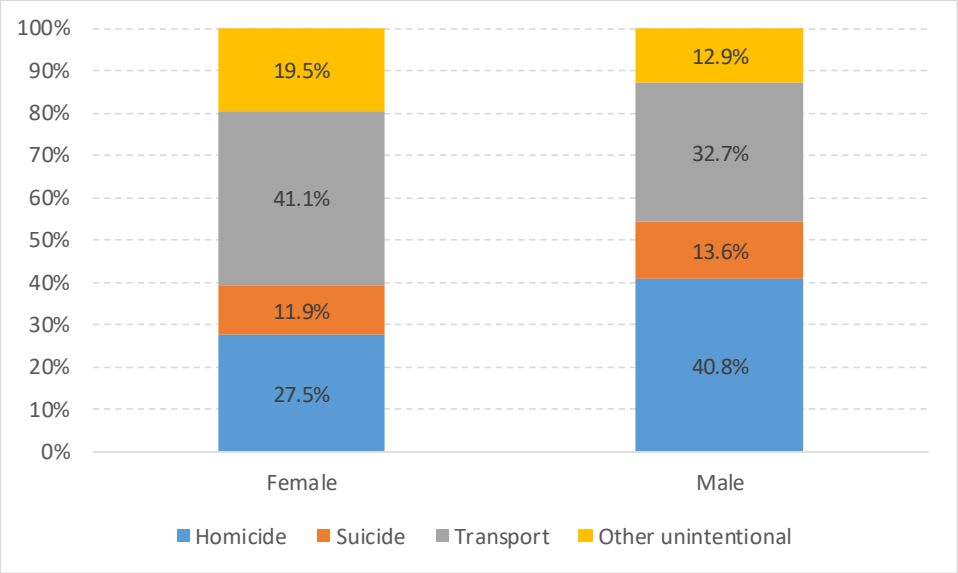

Figure 11. Predicted proportions of Model 7 (adjusting for age, sex and race) by sex and manner of death

Association 2 observed for *childhood other unintentional injury deaths* during the MCA in Figure 10, is reflected by the predicted proportions in Figure 12. The predicted proportions were highest for other unintentional injury deaths for those 0-14 years and were highest for Coloured children followed by Black children.

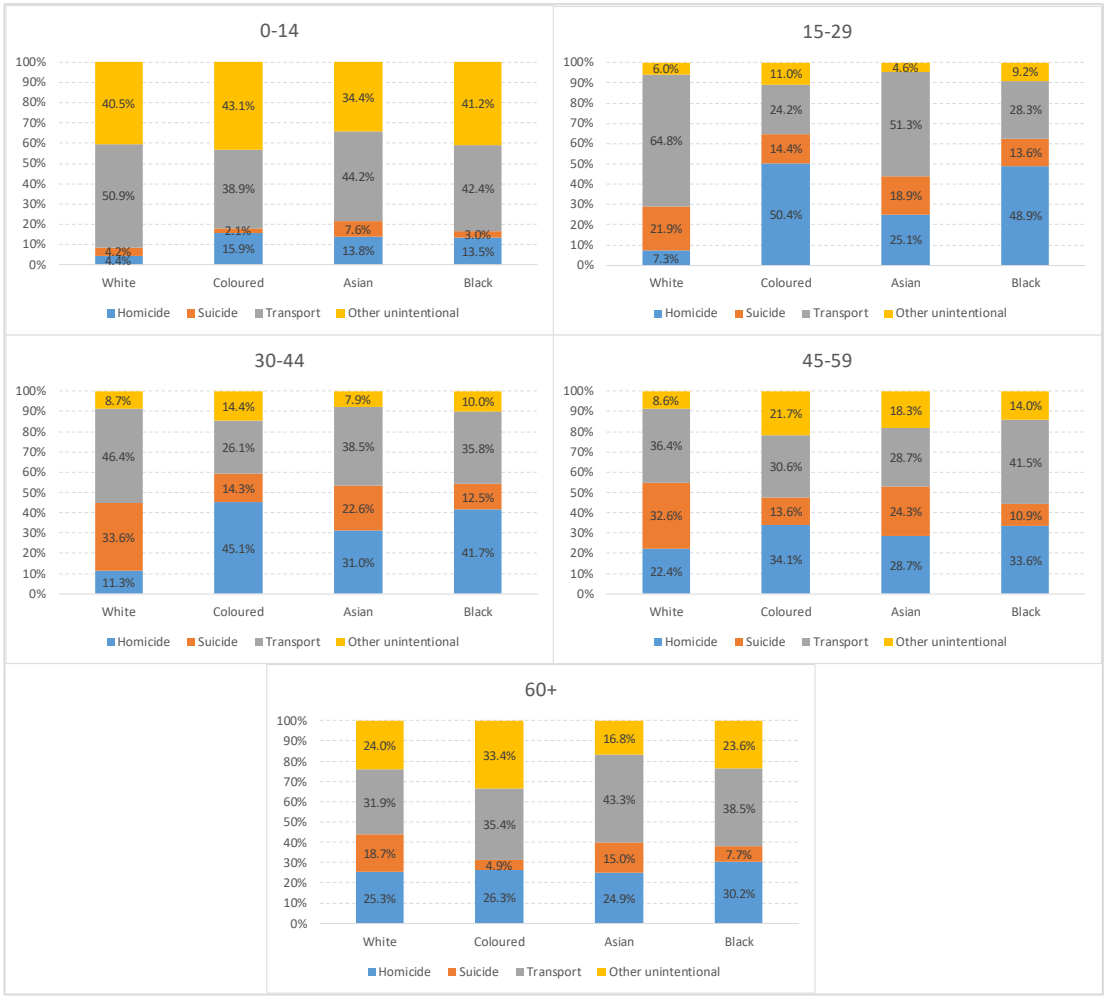

Figure 12. Predicted proportions of Model 7 (adjusting for age, sex and race), by race, age and manner of death

Although association 3 for *Asians and suicide 45-59 years* was indicated by the MCA, the model's predicted proportions (Figure 12) indicate similar proportions for homicide (28.7%), suicide (24.3%) and transport-related deaths for Asians 45-59 years (28.7%). Instead, a higher likelihood for suicide was found for Whites, 30-44 years (33.6%) and 45-59 years (32.6%).

Association 4 noted for *White transport-related deaths for the 45-59 year age-group* in Figure 10 was confirmed by the higher predicted proportions for transport-related deaths (36.4%) in Figure 12, but this was lower than for Blacks 45-59 years, who also had a higher likelihood of transport-related deaths (41.5%) than other manners of death for this age group.

The predicted proportions calculated from Model 7 indicate that *Asians (51.3%) and Whites (64.8%) aged 15-29 years* had a higher likelihood of transport-related death. This finding was not observed by the MCA in Figure 10.

Association 5 was confirmed by the predicted proportions in Figure 12, indicating that *Coloureds (50.4%) and Blacks (48.9%) aged 15-29 years had a significantly ($p<0.001$) higher likelihood for homicide* relative to other unintentional injury deaths. This association was also noted by the MCA clustering in Figure 10. The MLR and predicted proportions also indicate a significantly ($p<0.001$) higher likelihood for homicide for Coloureds (45.1%) and Blacks (41.7%) aged 30-44 years.

The predicted proportions by race and metro/non-metro in Figure 13 for Model 7 indicate that Whites, Asians and Blacks had a higher likelihood of transport-related deaths in non-metro areas, than in metro areas. The likelihood for homicide was highest for Blacks and Coloureds in metro areas, but in non-metro areas this was marginally higher for Coloureds compared to Blacks.

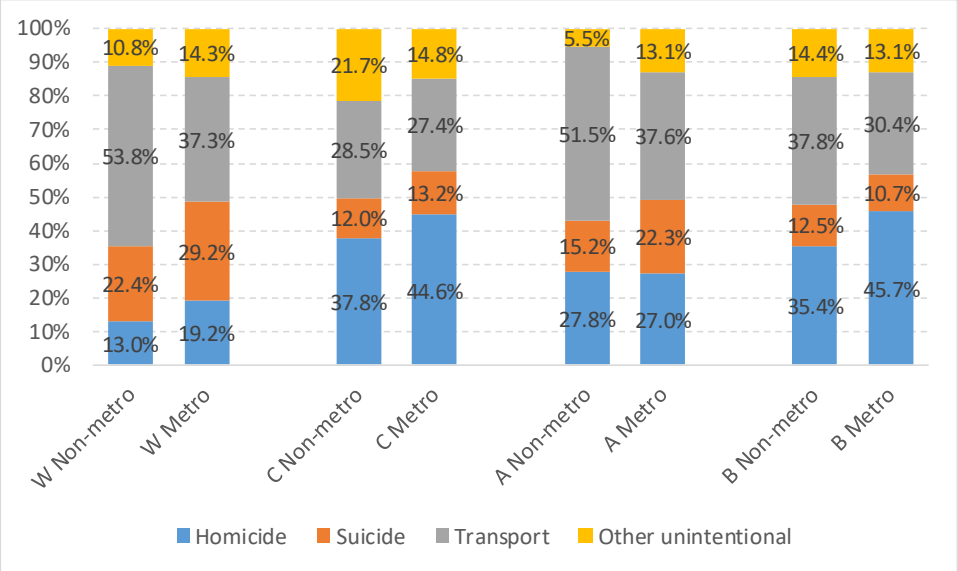

Figure 13. Predicted proportions of Model 7, adjusting for age, sex and race by metro-/non-metro area, manner of death and race

In summary, Model 1 indicated a significantly higher likelihood of homicide in metro areas, compared to non-metro areas, no difference between metro- and non-metro areas for suicide, and the likelihood of a transport-related death was significantly lower in metro areas than non-metro areas. This supports Hypothesis 1: *Homicide is*

higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas. The race*age and race*M/NM interaction in model 7 however, resulted in the metro/non-metro difference for homicide to not be significant.

Males had a significantly higher likelihood for homicide than females, while there was no difference between male and female transport-related deaths, relative to other unintentional injury deaths.

The likelihood for other unintentional injury deaths was highest for children 0-14 years and were highest for Coloured and Black children. A higher likelihood for suicide was found for Whites, 30-44 years and 45-59 years.

Whites 45-59 years had a higher likelihood for transport-related deaths but this was lower than for Blacks of the same age-group. The predicted proportions calculated from Model 7 also indicated that Asians and Whites aged 15-29 years had a higher likelihood for transport-related deaths. This finding was not observed by the MCA. Coloureds and Blacks aged 15-29 years and 30-44 years had a significantly higher likelihood for homicide relative to other unintentional injury deaths.

The model indicated a higher likelihood for transport-related deaths in non-metro areas, than in metro areas for Whites, Asians and Blacks. Blacks and Coloureds in metro areas had a higher likelihood for homicide, but in non-metro areas Coloureds had a marginally higher likelihood for homicide than Blacks.

6.3 Discussion

The purpose of this chapter was to systematically illustrate and interpret the observed associations in the MCA, which, along with a review of the literature, informed the selection of the variables for the MLR modelling.

The MLR modelling was used to identify statistical significance for the associations noted by the MCA, and to test Hypothesis 1: *Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas.* The

hypothesis was indeed supported, in that homicide was significantly higher in metro areas and transport-related death was significantly higher in non-metro areas (Model 1 in Table 15). Even though this was not noted by the MCA, the MLR analysis showed that metro/non-metro is a significant predictor of the injury mortality profile.

The MLR analysis for Model 7, with an age*race and race*M/NM interaction, identified via the model's predicted proportions in Figure 11 to Figure 13, particular public health targets for intervention. The chapter's findings for the metro/non-metro difference were supported by the analysis of the proportions for the injury mortality profile in Figure 6 of Chapter 5. In addition, the analysis of age-specific and age-standardised injury mortality rates by race and sex in Chapter 5 also identified the most important targets for public health interventions aimed at reducing injuries and violence, viz.

-Males for the prevention of homicide and females for the prevention of transport-related deaths

-Children 0-4 years for other unintentional injuries in metro areas

-Suicide for Whites, 30-44 years and 45-59 years

-Asians and Whites 15-29 years; Blacks and Whites 45-59 years for transport-related deaths in non-metro areas

-Black and Coloured males 15-29 and 30-44 years for homicide in metro areas

The results highlight the importance of using multiple methods to determine priorities for injury prevention policy initiatives, as not all the associations were noted by the MCA. The reason for this is that within large datasets, the percentage variance for the MCA is low, and there is a possibility that particular associations are not illustrated (Bock, 2017). The utility of the MLR analysis is demonstrated by the comparative findings of the proportions and rates, indicating that it might apply to future mortuary surveys in settings with poor demographic data.

While it is clear from the literature that the injury mortality profile for high-income countries is strongly influenced by transport-related deaths in rural areas, the preceding analysis indicated that South Africa's injury mortality profile is influenced by the metro-area homicide rates, which are discussed in greater detail in Chapter 7. The predicted proportions for the MLR analysis on homicide also provided foresight to the likely interaction terms and associations to be expected for homicide in Chapter 7.

7 THE CHARACTERISTICS OF HOMICIDE IN SOUTH AFRICA

Although there has not been any prior national comparison of metro- and non-metro area firearm homicide, trend analysis of five South African cities (Cape Town, Durban, Johannesburg, Port Elizabeth and Pretoria) indicated higher firearm homicide rates in the cities with large metro areas (Matzopoulos et al., 2014). Based on the reported firearm homicide literature for South African cities, Chapter 7 will use regression analysis to determine the explanatory variables for homicide in metro- and non-metro areas.

The results of this thesis have thus far met the objectives to "evaluate the quality of survey data"; and "to characterize the variables driving the urban-rural differences of fatal injuries in South Africa". Chapter 5 indicated that the quality of the survey data, evaluated according to the framework provided by Rao et al. (2005), could be considered good by comparison with vital registration data for South Africa (Prinsloo et al., 2017).

The MCA in Chapter 6 identified particular associations by categories of manner of death, age, sex and race and the MLR analysis identified whether those associations, along with additional associations were true and significant. Hypothesis 1: *Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas,* was supported in that the MLR modelling identified significantly higher homicide for metro areas and significantly higher transport-related deaths for non-metro areas.

An important finding in Chapter 5, was that the higher rates for total injury fatalities in metro areas were largely influenced by the high homicide rates. The age-standardised rate for homicide was significantly higher for Blacks in metro areas than non-metro areas. Homicide was also particularly high for 15-44 year old Blacks and Coloureds in metro- and non-metro areas. These findings indicate that homicide is clearly the driver of the metro/non-metro differences for injury deaths in South Africa.

Objective 5 of this thesis "*to determine the explanatory variables for homicide in urban and rural areas*" will be addressed by the exclusive analysis of homicide in this chapter.

Section 7.1 describes the age-standardised homicide rates by province for metro- and non-metro area and the age-specific homicide rates by province, sex and race for metro- and non-metro area. The IMS provincial homicide rates are compared with SAPS homicide rates to evaluate the validity of these data. Using a set of generalized linear models, the demographic factors are then considered to test the following hypotheses:

2) Age, sex, race are independently associated with homicide in both metro- and non-metro areas with specific sub-hypotheses;

2.1) Blacks experience a higher risk for homicide in metro areas than Coloureds; and Coloureds experience a higher risk for homicide in non-metro areas than Blacks;

2.2) The risk of homicide among males relative to the risk among females is greater in metro areas than in non-metro areas.

Section 7.2 considers the differences by day of week for metro- and non-metro areas and tests the following hypothesis:

3) Day of week is independently associated with homicide.

Section 7.3 describes the external causes of homicide and how the age-standardised rates differ for metro- and non-metro areas; how firearm- and non-firearm homicide rates differ by province, age, sex and race; and tests the following hypothesis:

4) *Metro/non-metro differences for homicide can be explained by firearm use*.

Section 7.4 discusses the findings in relation to the chapter's three hypotheses and relevant sub-hypotheses.

7.1 Characteristics of metro and non-metro homicide

7.1.1 Metro versus non-metro provincial characteristics of homicide

Figure 8 in Chapter 5 indicated the regional variation in the number of homicides across the nine provinces. Table XII in Appendix III shows the proportional distribution of homicide by metro- and non-metro area for the nine provinces. This section identifies the metro versus non-metro differences in homicide rates within each province (Table 18). To recap the classification of metro- and non-metro areas explained in Chapter 4, the Eastern Cape, KwaZulu-Natal, Western Cape and Gauteng have large urban metropolitan areas, while the non-metro areas were found in all provinces except Gauteng, which was exclusively metro. The Eastern Cape's age-standardised rate (ASR) for homicide was 57.9 per 100 000 and was the highest of all provinces (Table 18), 1.5 times the national average for 2009. The most pronounced metro/non-metro difference was in KwaZulu-Natal, where the metro homicide rate (72.3 per 100 000) was 1.9 times higher than the non-metro rate. The Western Cape's metro homicide rate was marginally higher than that province's non-metro rate and the provincial ASR of 40.1 was closest to the national average of 38.4 per 100 000.

Table 18. Age-standardised homicide rates (ASR) by province and area based on the Injury Mortality Survey (IMS), SA 2009 (N= 19 028)

Provincial ranking	Homicide Metro ASR (95% CI)	Homicide Non-metro ASR (95% CI)	Homicide Provincial ASR (95% CI)
1) Eastern Cape (EC)	62.2 (9.4-115.5)	55.4 (8.4-102.8)	57.9 (20.9-94.9)
2) Northern Cape (NC)		53.6 (4.2-104.6)	53.6 (4.2-104.6)
3) KwaZulu-Natal (KZN)	72.3 (30.6-114.0)	37.9 (19.3-56.5)	50.8 (31.1-70.4)
4) Western Cape (WC)†	41.8	37.0	40.1
5) Gauteng (GT)	36.2 (19.2-53.2)		36.2 (19.2-53.2)
6) Free State (FS)		35.3 (10.0-60.7)	35.3 (10.0-60.7)
7) North West (NW)		25.1 (7.6-42.5)	25.1 (7.6-42.5)
8) Limpopo (LP)		18.8 (3.8-34.1)	18.8 (3.8-34.1)
9) Mpumalanga (MPU)		17.5 (4.0-31.1)	17.5 (4.0-31.1)
South Africa (SA)	45.1 (37.3-52.9)	33.2 (25.0-41.4)	38.4 (33.6-43.3)

†The Western Cape data includes the full sample of 18 mortuaries and hence has no confidence interval.
Source: Prinsloo *et al*, 2016

7.1.2 Validation of homicide rates

The South African Police Service (SAPS) data for 2009 (SAPS, 2014) was the only national source which could be used to validate the IMS homicide data for the nine provinces. Crude rates (CR) for homicide were calculated for the IMS to be comparable with SAPS (Figure 14). The SAPS report their homicide rates per financial year (April 2009-March 2010) and the IMS per calendar year (January-December 2009), resulting in small discrepancies. However, as mentioned in Chapter 5, the SAPS had 2 194 (13%) fewer cases recorded in comparison to the IMS (Matzopoulos et al., 2015).

A comparison of the two data sources validated the finding that the Eastern Cape had the highest homicide rate for 2009 (Figure 14). The provincial rankings were similar for the two data sources, with the exception of two provinces. The Western Cape's homicide rates ranked second highest for SAPS but fourth highest for the IMS and this was largely due to the lower homicide rates reported by SAPS for the Northern Cape. The IMS homicide rate for the Northern Cape was 1.6 times higher than that reported by SAPS, resulting in the largest discrepancy (Prinsloo et al., 2016).

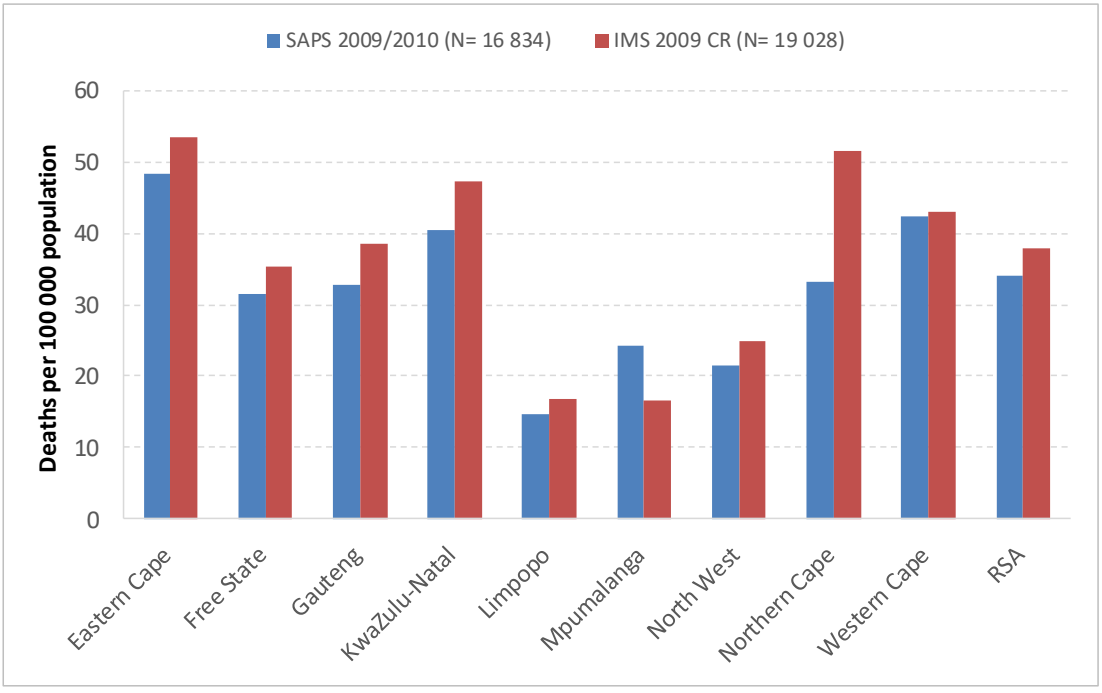

Figure 14. Validation of IMS and SAPS homicide crude rates
Source: Adapted from Prinsloo et al. (2016)

7.1.3 Age, sex and race characteristics of homicide

It is known from the review of the literature in Chapter 2 that age, sex and race are explanatory factors for homicide and these are explored in the section to follow.

The metro homicide differences by province and age in Figure 15a, indicate that the rates were highest in KwaZulu-Natal, particularly for the 15-29 and 30-44 year age groups. The Eastern Cape metro area had a similar profile to KwaZulu-Natal. The Western Cape metro areas had a distinct peak in the 15-29 year age group, followed by a sharp decline in the older age groups. The homicide rate for Gauteng was much lower in comparison to the other metro-area provinces.

In Figure 15b the non-metro areas of the Eastern Cape had the same peak in rates at 15-29 years, but rates for the older ages remained high. The Northern Cape's 30-44 year age group had the highest rates for non-metro areas. Besides the non-metro Eastern Cape, the case numbers for the remaining provinces were low for age 70 years and older and the rates should be interpreted with caution. The Free State, North West, Limpopo and Mpumalanga provinces had lower homicide rates (Figure 15b).

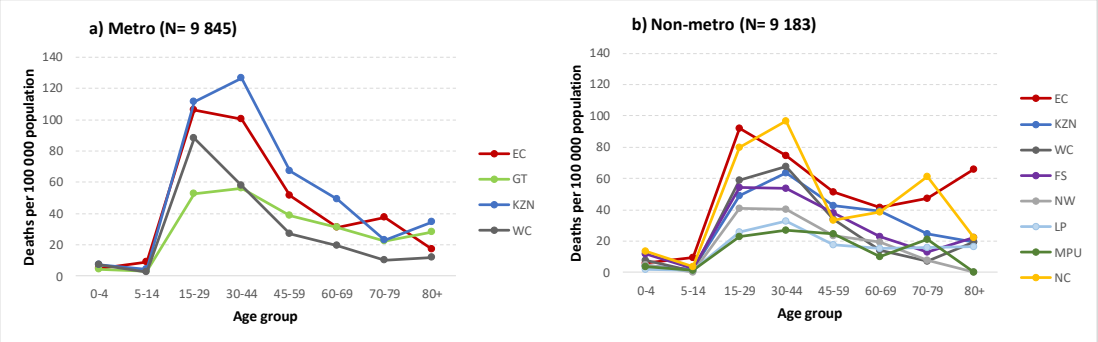

Figure 15. Age-specific homicide rates by province and area, SA 2009 (N= 19 028)

For males, the homicide rate in metro areas (Figure 16a) peaked in the 15-29 year age group (132.8 per 100 000 population) while in non-metro areas (Figure 16b), it peaked in the 30-44 year age group at a lower level (96.6 per 100 000). Similar rates for females across metro- and non-metro areas were found, except for the 70-79 year age group in non-metro areas, where rates were higher than the metro areas.

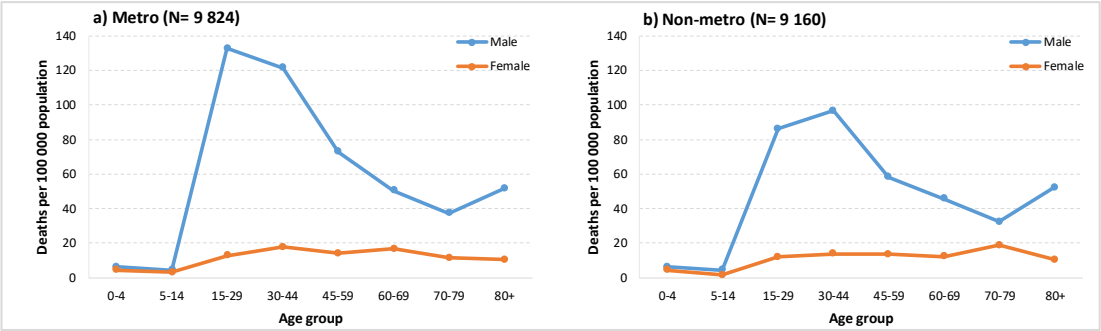

Figure 16. Age-specific homicide rates by sex and metro- and non-metro area, South Africa 2009

The age-specific homicide rates by race showed a peak in the 15-29 and 30-44 year age groups for Blacks in metro areas (Figure 17a), while Coloureds peaked in the 15-29 year age group and declined in the older ages. Case numbers for Asians aged 80 years and older were very low and their homicide rates should be interpreted with caution. The profile for Whites differed from the other race groups, as homicide rates increased with age and peaked in the 60-69 year age group in metro areas and the 45-59 year age group in non-metro areas (Figure 17b). In non-metro areas homicide rates peaked in the 30-44 year age group for Coloureds, with a sharp decline in older ages, while it peaked in the 15-29 year age group for Asians. Black homicide rates peaked in the same age group as Coloureds but had a more gradual decline in the older ages, where homicide rates remained relatively high.

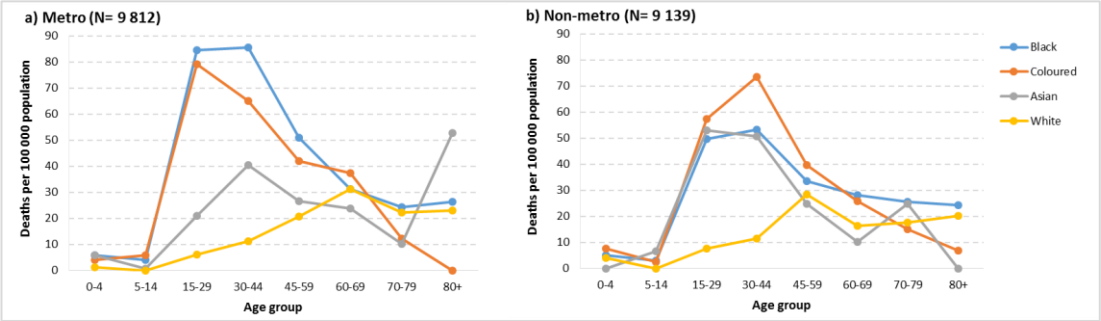

Figure 17. Age-specific homicide rates by race and metro- and non-metro area, South Africa 2009 (N= 18 951)

Table 11 in Chapter 5 indicates that the 15-29 year metro homicide rate (73.6 per 100 000; 95% CI: 62.2-84.9) was significantly higher than the non-metro homicide rate (48.8 per 100 000; 95% CI: 35.9-61.6). Table 13 in Chapter 5 indicated that it was only significantly different for Blacks in metro (52.6; 95% CI: 44.6-60.5) and non-metro areas (33.8; 95% CI: 24.6-43.0).

In summary, the homicide rates in metro-areas peaked for Blacks, 15-44 years and Coloureds 15-29 years. In non-metro areas the homicide rates also peaked for Blacks, 15-44 years, while Coloureds peaked at an older age-group of 30-44 years. While Black and Coloured homicide rates were both relatively high, the Black homicide rates differed from Coloureds in the older ages, where it remained relatively high and similar to Whites, who had higher rates in the older ages. The peaks in Black and Coloured homicide rates for 15-29 and 30-44 year olds in Figure 17a are similar to the profiles observed for the Eastern Cape, KwaZulu-Natal and the Western Cape metro areas (Figure 15a), while the peak for 30-44 year old Coloureds, Blacks and Asians (Figure 17b) are similar to the profiles for the Northern Cape, Eastern Cape, Western Cape and KwaZulu-Natal in non-metro areas (Figure 15b).

Section 7.1.4 will explore how these demographic factors predict the risk of homicide. In addition, section 7.2 will consider day of week as explanatory variable, while section 7.3 provides an overview of the external causes of homicide and explores firearm use as explanatory variable for homicide in metro- and non-metro areas. Table 19 provides a summary of the goodness of fit statistics of the models considered in this chapter, with the relevant explanatory variables and interaction terms, which were selected based on a review of the risk factor literature for homicide and from the results of the MLR analysis in Chapter 6 to test specific hypotheses. Following the analysis of proportions via the MLR analysis to determine the injury mortality profile, the generalized linear modelling on homicide in the next section, will take the population at risk into account.

Table 19. Summary table of models and goodness of fit statistics

Model	Log likelihood	Deviance	AIC	BIC
1) Metro/Non-metro (M/NM)	-7665.6	0.54	2.28	-55602.0
2) M/NM, race	-7581.5	0.54	2.26	-55550.8
3) M/NM, race, sex	-7305.9	0.55	2.18	-55485.9
4) M/NM, race, sex, age	-7051.5	0.56	2.10	-55356.2
5) M/NM, race, sex, age, race*M/NM	-7042.2	0.56	2.10	-55339.3
6) M/NM, race, sex, age, sex*M/NM	-7050.5	0.56	2.10	-55345.1
7) M/NM, race, sex, age, Day of Week (DoW)	-7024.6	0.57	2.10	-55260.2
8) M/NM, race, sex, age, FA/NFA, FA/NFA*M/NM	-6853.7	0.59	2.04	-55191.6

7.1.4 Demographic factors as explanatory variables for homicide

The higher homicide rates for males and Blacks in metro areas versus non-metro areas are in keeping with the findings of the literature review in Chapter 2.

In order to address *Hypothesis 2*, that *age, sex and race are independently associated with homicide* in both metro- and non-metro areas, negative binomial regression will be applied using a generalized linear model, as explained in section 4.3.4 of Chapter 4. Table 20 shows when only considering metro- and non-metro area, unadjusted for other covariates within the model, the relative risk for homicide is significantly higher in metro areas (IRR=1.42; p<0.001).

Table 20. Model 1 including Metro-/Non-metro (M/NM)

Model	Log likelihood	Deviance	AIC	BIC
1) Metro/Non-metro (M/NM)	-7665.6	0.54	2.28	-55602.0
	IRR	**p-value**	**95% Confidence Interval**	
Non-metro (ref)	1.00			
Metro	1.42	<0.001	1.24	1.62

When considering race as an independent explanatory variable for homicide, Model 2 in Table 21 indicates that there was no real change to the relative risk of homicide in metro areas. The risk of homicide among Blacks (IRR=3.09; 95% CI=2.58-3.69) and Coloureds (IRR=3.00; 95% CI=2.48-3.64) were approximately three times higher and significantly different (p<0.001) from Whites as the reference category.

When adding sex as an independent explanatory variable for homicide in Model 3 (Table 21), the relative risk for males was 5.2 times higher in comparison to females. Although the relative risk for homicide among Blacks was marginally lower than Coloureds, the confidence intervals for the two race groups indicated that there was no real change in the model and confounding by sex was therefore not evident.

Table 21. Models 2-4, with M/NM, adding race, sex and age

Model	Log likelihood	Deviance	AIC	BIC
2) M/NM, race	-7581.5	0.54	2.26	-55550.8
	IRR	**p-value**	**95% Confidence**	

			Interval	
M/NM:				
Non-metro (ref)	1.00			
Metro	1.37	<0.001	1.20	1.57
Race:				
White (ref)	1.00			
Coloured	3.00	<0.001	2.48	3.64
Asian	2.00	<0.001	1.56	2.58
Black	3.09	<0.001	2.58	3.69
Model	**Log likelihood**	**Deviance**	**AIC**	**BIC**
3) M/NM, race, sex	-7305.9	0.55	2.18	-55485.9
	IRR	**p-value**	**95% Confidence Interval**	
M/NM:				
Non-metro (ref)	1.00			
Metro	1.31	<0.001	1.16	1.49
Race:				
White (ref)	1.00			
Coloured	3.01	<0.001	2.50	3.62
Asian	1.85	<0.001	1.45	2.35
Black	2.78	<0.001	2.35	3.29
Sex:				
Female (ref)	1.00			
Male	5.17	<0.001	4.55	5.87
Model	**Log likelihood**	**Deviance**	**AIC**	**BIC**
4) M/NM, race, sex, age	-7051.5	0.56	2.10	-55356.2
	IRR	**p-value**	**95% Confidence Interval**	
M/NM:				
Non-metro (ref)	1.00			
Metro	1.30	<0.001	1.15	1.46
Race:				
White (ref)	1.00			
Coloured	3.02	<0.001	2.53	3.62
Asian	1.79	<0.001	1.42	2.26
Black	2.75	<0.001	2.34	3.23
Sex:				
Female (ref)	1.00			
Male	4.57	<0.001	4.06	5.15

Age:				
45-59 (ref)	1.00			
0-14	0.11	<0.001	0.09	0.13
15-29	1.10	0.286	0.93	1.30
30-44	1.26	0.008	1.06	1.49
60+	0.83	0.054	0.69	1.00

When adding age as an independent explanatory variable for homicide in Model 4 (Table 21), the 15-29 and 30-44 year age groups were at higher risk for homicide, in comparison to the 45-59 year age group as the reference category. This finding was significant (p=0.008) for the 30-44 year age group. This is consistent with the observed data depicted by the earlier graphs for homicide rates. The addition of age did not significantly alter the parameters for the explanatory variables, indicating that confounding was not evident. The log likelihood, deviance, AIC and BIC values indicate that the addition of age improved the model fit (Table 19).

Models 1-4 indicate that no confounding was evident for the association between metro/non-metro and homicide (Table 21). Age, sex and race are significantly associated with homicide, without changing the unadjusted association observed with metro/non-metro. This satisfies Hypothesis 2, *that age, sex and race are independently associated with homicide in both metro- and non-metro areas.*

Model 5 shows that there is effect modification by race and metro/non-metro, with statistically significant two-way interaction terms. Figure 18 (based on this model) indicates that having taken age and sex effects into account, for metro areas, the risk of homicide is highest for Coloureds, followed by Blacks, Asians and Whites. However, for non-metro areas, the risk of homicide is similar for Coloureds, Blacks and Asians, and much lower for Whites. This finding is not consistent with the age-standardised homicide rates by race and metro/non-metro in Table 13 of Chapter 5, where the ASR for homicide among Blacks was higher in metro areas (52.6 per 100 000; CI: 44.6-60.5) than among Coloureds in metro areas (45.3 per 100 000; CI: 26.8-63.7). In contrast, in non-metro areas the ASR for homicide among Coloureds was higher (40.2 per 100 000; CI: 22.0-58.6) than among Blacks in non-metro areas (33.8 per 100 000; CI: 24.6-43.0). Thus rejecting sub-hypothesis 2.1, that Blacks experience a higher risk for homicide in metro areas than Coloureds; and Coloureds

experience a higher risk for homicide in non-metro areas than Blacks. Figure 18 also indicates that Whites and Asians have a very different metro/non-metro pattern. While for Whites the homicide risk is similar for metro- and non-metro areas, Asians have an inverse relationship to that for Blacks and Coloureds. These findings warrant further investigation to the extent and likely motive for homicide in non-metro areas.

Table 22. Model 5 with M/NM, race, sex, age & race*M/NM

Model	Log likelihood	Deviance	AIC	BIC
*5) M/NM, race, sex, age, race*M/NM*	-7042.2	0.56	2.10	-55339.3
	IRR	**p-value**	**95% Confidence Interval**	
M/NM:				
Non-metro (ref)	1.00			
Metro	1.03	0.810	0.79	1.35
Race:				
White (ref)	1.00			
Coloured	2.46	<0.001	1.94	3.12
Asian	2.34	<0.001	1.68	3.26
Black	2.40	<0.001	1.95	2.96
Sex:				
Female (ref)	1.00			
Male	4.50	<0.001	4.00	5.07
Age:				
45-59 (ref)	1.00			
0-14	0.11	<0.001	0.09	0.13
15-29	1.08	0.354	0.91	1.28
30-44	1.26	0.007	1.06	1.49
60+	0.84	0.072	0.70	1.02
*Race*M/NM:*				
White*NM (ref)	1.00			
Coloured*M	1.59	0.010	1.12	2.25
Asian*M	0.67	0.086	0.43	1.06
Black*M	1.38	0.046	1.01	1.90

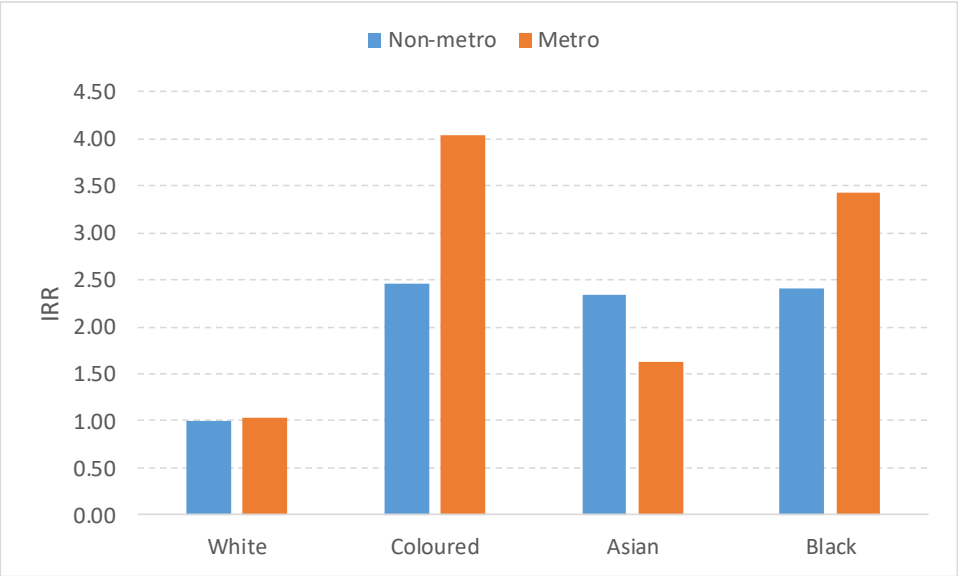

Figure 18. Race*M/NM interaction for Model 5

Figure 19 shows the age-specific homicide rates by race and sex to explore the effect modification between race and metro/non-metro. In general, there is little difference in homicide rates between Blacks and Coloureds in metro or non-metro areas with the exception of non-metro areas for females. Female coloured homicide rates in non-metro areas (Figure 19d) were substantially higher than that among Blacks.

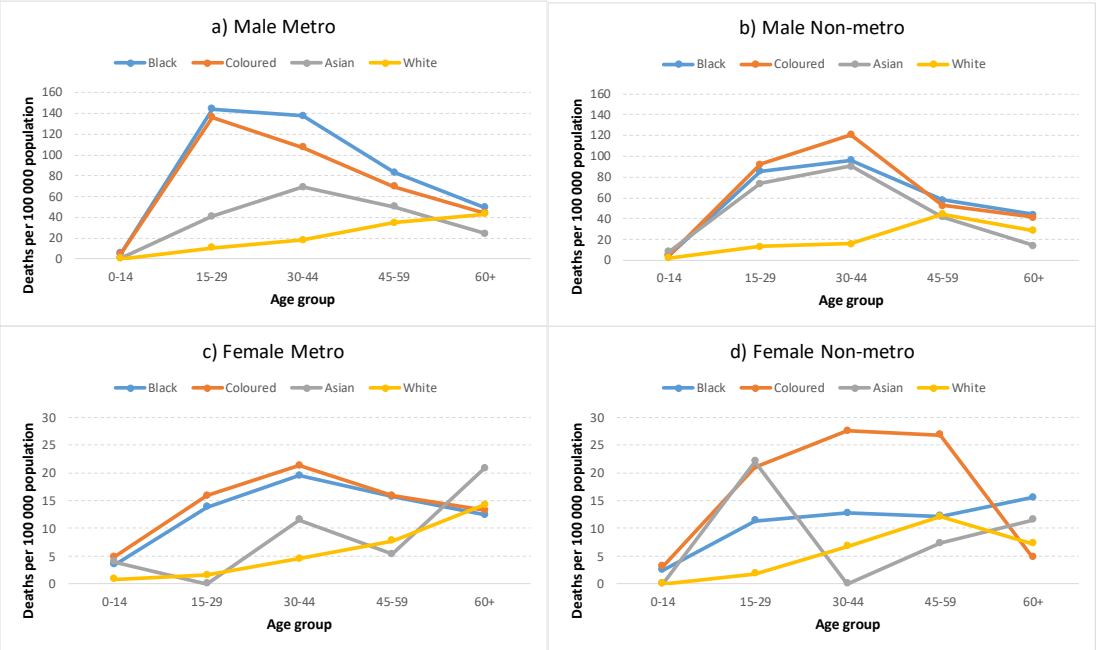

Figure 19. Age-specific homicide rates by sex and race in metro- and non-metro areas, SA 2009

The sex*metro/non-metro interaction in Table 23 and Figure 20 investigated in Model 6, indicates that the risk for male homicide relative to female homicide in metro

areas was higher than the risk for male homicide relative to female homicide in non-metro areas. However, this interaction was not statistically significant (p=0.168). This does not support sub-hypothesis 2.2, that *the risk of homicide among males relative to the risk among females is greater in metro areas than in non-metro areas.* This is consistent with the age-standardised rates for homicide (Table 12 in Chapter 5), which indicates that the male homicide rate is higher for metro-areas (78.3 per 100 000; CI: 65.2-91.4) than non-metro areas (58.5 per 100 000; CI: 43.9-73.1), but has overlapping confidence intervals.

Table 23. Model 6 with M/NM, race, sex, age & sex*M/NM

Model	Log likelihood	Deviance	AIC	BIC
*6) M/NM, race, sex, age, sex*M/NM*	-7050.5	0.56	2.10	-55345.1
	IRR	**p-value**	**95% Confidence Interval**	
M/NM:				
Non-metro (ref)	1.00			
Metro	1.17	0.105	0.97	1.41
Race:				
White (ref)	1.00			
Coloured	3.01	<0.001	2.51	3.59
Asian	1.78	<0.001	1.41	2.26
Black	2.73	<0.001	2.32	3.21
Sex:				
Female (ref)	1.00			
Male	4.26	<0.001	3.64	4.97
Age:				
45-59 (ref)	1.00			
0-14	0.11	<0.001	0.09	0.13
15-29	1.10	0.287	0.93	1.30
30-44	1.26	0.007	1.07	1.50
60+	0.83	0.056	0.69	1.00
*Sex*M/NM:*				
Female*NM (ref)	1.00			
Male*M	1.18	0.168	0.93	1.50

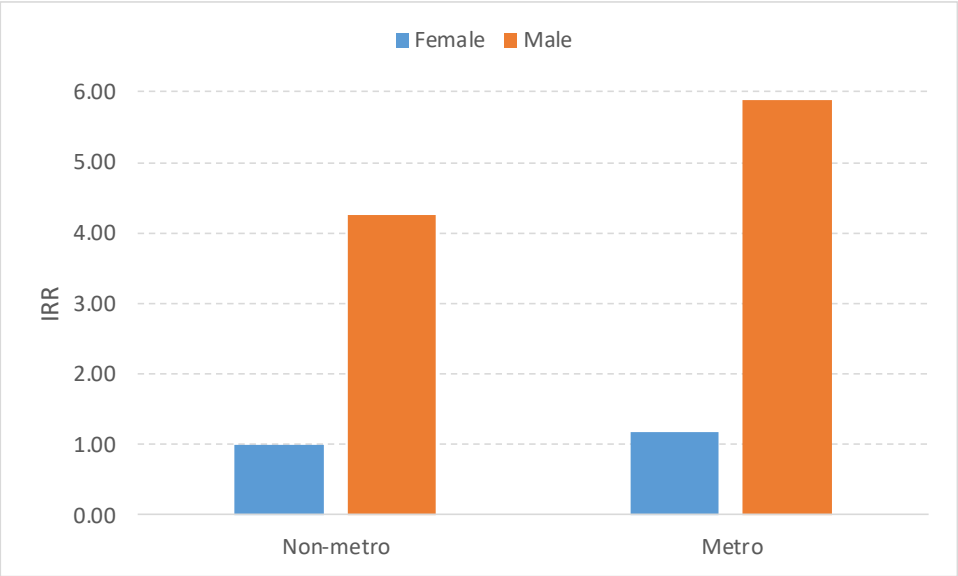

Figure 20. Sex*M/NM interaction for Model 6

7.2 Day of week as explanatory variable for homicide

The blood alcohol data for the IMS study was not nationally representative. Hence, day of week was used as a proxy for increased social interaction and alcohol consumption (Matzopoulos, 2012), as it has been associated with increased levels of violence (Graham & Livingston, 2011). Homicide in metro and non-metro areas were high over the weekend and peaked on Saturdays (Figure 21). The largest difference between metro and non-metro deaths was also observed on a Saturday, where the proportion of deaths in non-metro areas were higher and more than double that recorded on Fridays. The lowest proportion of deaths occurred on a Wednesday. Pearson's chi squared test showed that the difference between metro- and non-metro area were significant (x^2= 45.51, p=0.02). As the analysis indicated homicide rates were higher in metro areas and that deaths were highest over weekends, the third hypothesis is that *day of week is independently associated with homicide.*

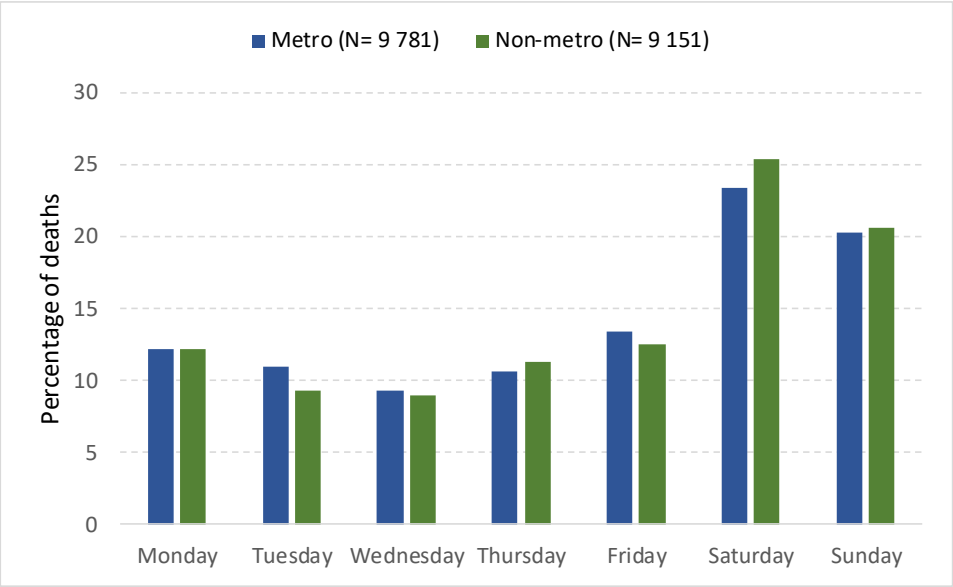

Figure 21. Homicide by day of week for metro- and non-metro areas, South Africa 2009

Model 7 in Table 24 considers day of week as explanatory variable, which indicated that the risk of homicide was significantly higher over weekends. This model did not change the other explanatory variables by any great magnitude, which indicates that confounding was not evident and thus supports the third hypothesis, that *day of week is independently associated with homicide*. Since the addition of day of week did not alter the relative risks of the model by any great magnitude nor greatly improved the model fit, this variable will be excluded in the GLMs to follow in section 7.3.

Table 24. Model 7 with M/NM, race, sex, age, Day of Week (DoW)

Model	**Log likelihood**	**Deviance**	**AIC**	**BIC**
7) M/NM, race, sex, age, Day of Week (DoW)	-7024.6	0.57	2.09	-55260.2
	IRR	**p-value**	**95% Confidence Interval**	
M/NM:				
Non-metro (ref)	1.00			
Metro	1.30	<0.001	1.16	1.46
Race:				
White (ref)	1.00			
Coloured	2.90	<0.001	2.43	3.46

Asian	1.77	<0.001	1.40	2.23
Black	2.65	<0.001	2.26	3.10
Sex:				
Female (ref)	1.00			
Male	4.49	<0.001	4.00	5.05
Age:				
45-59 (ref)	1.00			
0-14	0.11	<0.001	0.09	0.13
15-29	1.07	0.455	0.90	1.26
30-44	1.25	0.010	1.05	1.47
60+	0.86	0.103	0.71	1.03
DoW:				
Wednesday (ref)	1.00			
Sunday	1.60	<0.001	1.29	1.98
Monday	1.20	0.099	0.97	1.50
Tuesday	1.09	0.423	0.88	1.37
Thursday	1.06	0.625	0.85	1.32
Friday	1.30	0.019	1.04	1.62
Saturday	1.83	<0.001	1.48	2.26

7.3 External causes of homicide and associated characteristics

This section will address the external cause of injury (i.e. sharp force, firearm, blunt force, etc.), which determines the severity of injuries and likelihood of death due to violence. The availability of weapons and their use in the initial assault influences the mortality rate. Sharp force assaults (41.8%) was the leading external cause of the 19 028 homicides, followed by firearms (29.0%). However, firearms was the leading external cause in metro areas (38.5% of all metro-area homicides), while it only accounted for 18.8% of homicide in non-metro areas. Firearms are regarded as more lethal in comparison to blunt force assault for instance, and it was not surprising to note that this was the most pronounced metro/non-metro difference for external cause of death for homicide: 2.7 times higher in metro areas (Table 25). Hence, this section will focus on firearm vs non-firearm homicide in metro- and non-metro areas. Sharp

force homicide was marginally higher in non-metro areas, while blunt force was higher in metro areas.

Table 25. Age-standardised homicide rates by external cause, 2009 (N= 19 028)

	Metro	Non-metro	Total
Sharp force	14.8 (12.3 - 17.4)	16.0 (12.2 - 19.8)	15.4 (13.3 - 17.6)
Firearm	17.2 (14.8 - 19.7)	6.3 (4.3 - 8.3)	11.2 (9.7 - 12.4)
Blunt force	10.5 (7.8 - 13.2)	8.0 (5.8 - 10.3)	9.1 (7.6 - 10.6)
Strangled	1.1 (0.6 - 1.6)	1.2 (0.7 - 1.8)	1.2 (0.8 - 1.5)
Other[c]	1.4 (0.9 - 2.0)	1.6 (0.7 - 2.5)	1.5 (0.9 - 2.1)
Homicide	45.1 (37.7 - 52.5)	33.2 (25.2 - 41.1)	38.4 (33.8 - 43.0)

[c] "Other" accounted for 3.6% of all homicide and included poison ingestion, fire, abandoned babies, pushed, drowning, gassing, crushing, electrocution and unknown causes of homicide.

7.3.1 Firearm- and Non-firearm homicide characteristics

The following section identifies differences in firearm- and non-firearm age-standardised homicide rates by province, race and age, which all contribute to the variation in homicide rates across South Africa. Figure 22 shows that the highest age-standardised firearm homicide rates were in KwaZulu-Natal (21.7 per 100 000) and Gauteng (14.2 per 100 000), while the highest non-firearm homicide rates were in the Northern Cape (51.3 per 100 000) and Eastern Cape (47.9 per 100 000).

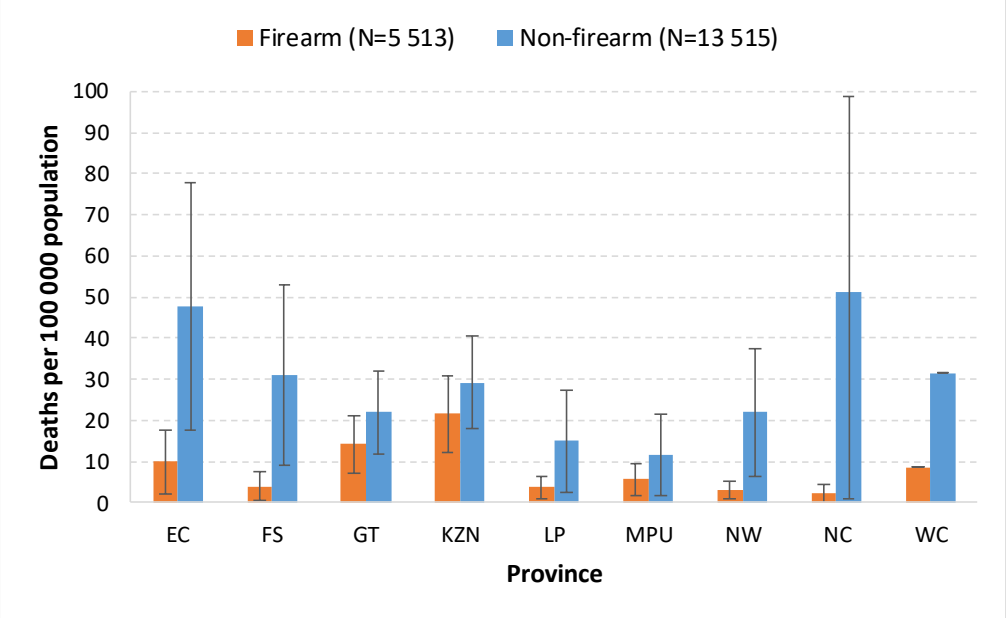

Figure 22. Age-standardised firearm and non-firearm homicide rates by province, SA 2009

Figure 23 indicates that the homicide rates for females were considerably lower than males and there was no large difference for female firearm homicide in metro- and non-metro areas (Figure 23a and Figure 23b). Female non-firearm homicide rates in metro- and non-metro areas (Figure 23c and Figure 23d) were marginally higher than firearm homicide rates and remained constant from 15-59 years.

Male metro firearm homicide rates (Figure 23a) peaked from 15-29 and 30-44 years and was between 2.5 to 3 times higher in comparison with the same age groups for non-metro firearm homicide rates (Figure 23b). The male non-firearm homicide rates (Figure 23c) peaked for the 15-29 year age group in metro areas and was 1.2 times higher than those 15-29 years in non-metro areas (Figure 23d). The male non-firearm homicide rates in non-metro areas (Figure 23d) peaked in the 15-29 and 30-44 year age groups, where it was highest in the latter with rates 1.2 times higher than metro areas for the same age group.

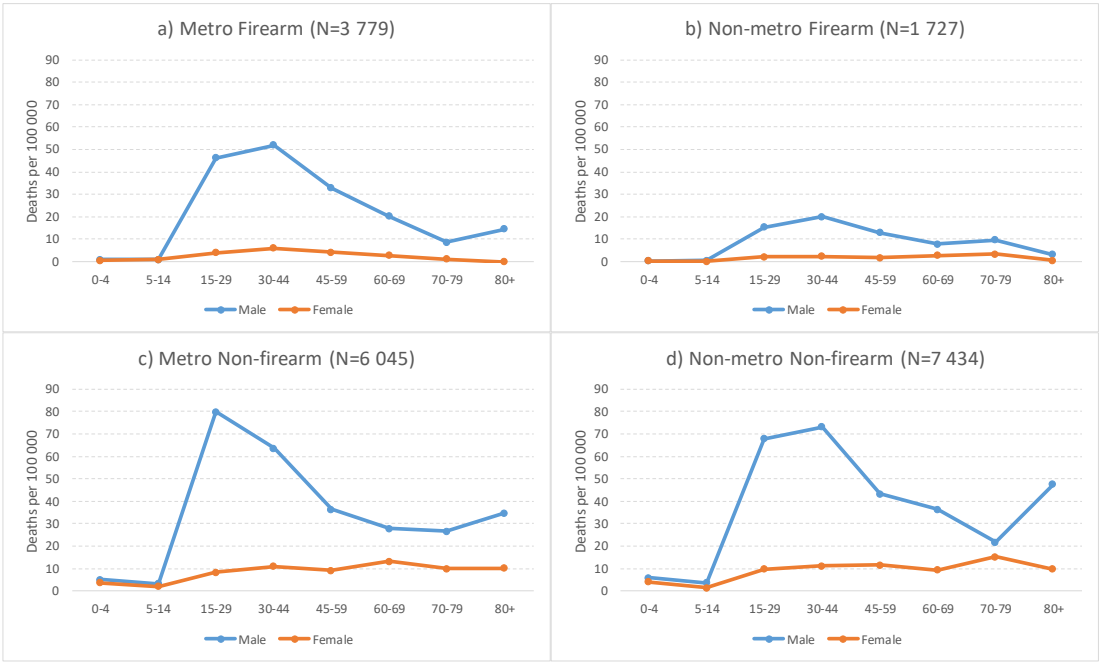

Figure 23. Age-specific homicide rates by sex in metro- and non-metro areas, SA 2009 (N= 18 985)

For race, firearm homicide rates peaked in the 30-44 year age group for Asians and Blacks (Figure 24a), followed by Coloureds 15-29 years. For Whites firearm homicide peaked at an older age (45-59 years), where rates were similar to Blacks and higher than Coloureds of the same age group. For non-firearm homicide (Figure 24b), Coloureds peaked between the ages of 15-44 years followed by a sharp decline. A

similar peak was observed for Blacks, but rates remained high in the elderly. Non-firearm homicide rates among Whites increased with age.

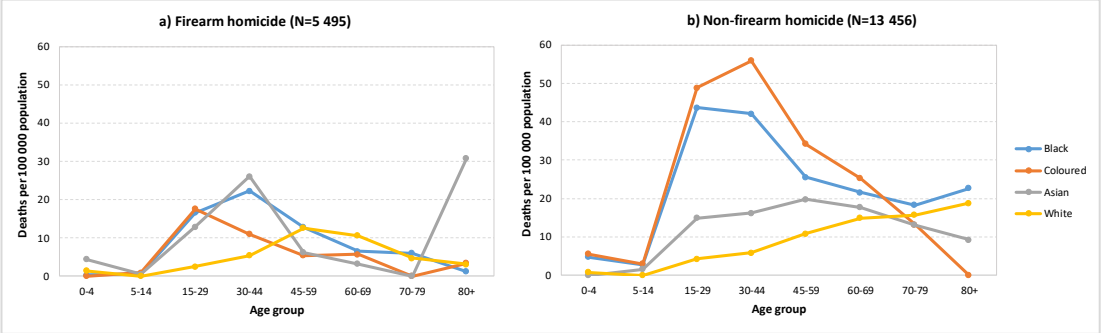

Figure 24. Age-specific homicide rates by race, SA 2009 (N= 18 951)

In summary this section identified that the firearm homicide rate was 2.7 times higher in metro areas and also confirmed that firearm homicide rates were higher in the provinces with major metropolitan, urbanized cities (Figure 22). Figure 23 and Figure 24 also identified differences by age, sex and race for firearm and non-firearm homicide. Male metro firearm homicide rates for 15-29 and 30-44 years were considerably higher than male non-metro firearm homicide rates of the same age. Firearm homicide rates peaked for Blacks and Asians 30-44 years, and at a younger age for Coloureds (15-29 years). Non-firearm homicide rates peaked for Coloureds and Blacks 15-44 years and was high for elderly Whites.

Based on the findings of the literature review, section 7.3.2 will address *Hypothesis 4*: that *metro/non-metro differences for homicide can be explained by firearm use,* by testing in Model 8, whether there is a significant interaction between metro-/non-metro with firearm- and non-firearm homicide.

7.3.2 Firearm- and non-firearm external cause of death as explanatory variable for homicide

The metro/non-metro interaction with firearm- and non-firearm homicide in Model 8 (Table 26 and Figure 25) shows that there is a significant interaction between firearm homicide and metro/non-metro ($p<0.001$) . This indicates that there is effect modification for firearm and non-firearm with metro/non-metro. Figure 24 shows that having adjusted for age, sex and race differences, the firearm homicide in metro areas is 2.6 times higher than for non-metro areas, while there is no difference in non-firearm homicide between metro- and non-metro areas. This finding is consistent with the age-

specific homicide rates for firearm/non-firearm and sex in metro- and non-metro areas in Figure 23a and b; and supports hypothesis 4, that *metro/non-metro differences for homicide can be explained by firearm use.* This highlights that firearms are one of the drivers of the higher rates in metro areas.

Table 26. Model 8 with M/NM, race, sex, age and a FA/NFA*M/NM interaction

Model	Log likelihood	Deviance	AIC	BIC
*8) M/NM, race, sex, age, FA/NFA, FA/NFA*M/NM*	-6853.7	0.59	2.04	-55191.6
	IRR	**p-value**	**95% Confidence Interval**	
M/NM:				
Non-metro (ref)	1.00			
Metro	1.06	0.379	0.93	1.23
Race:				
White (ref)	1.00			
Coloured	2.59	<0.001	2.18	3.07
Asian	1.68	<0.001	1.34	2.10
Black	2.50	<0.001	2.14	2.91
Sex:				
Female (ref)	1.00			
Male	4.89	<0.001	4.38	5.47
Age:				
45-59 (ref)	1.00			
0-14	0.10	<0.001	0.08	0.12
15-29	1.07	0.380	0.92	1.25
30-44	1.26	0.003	1.08	1.48
60+	0.80	0.014	0.67	0.96
Homicide type:				
Non-firearm (ref)	1.00			
Firearm	0.22	<0.001	0.19	0.26
*Homicide type*M/NM:*				
NFA*NM (ref)	1.00			
FA*M	2.40	<0.001	1.93	2.98

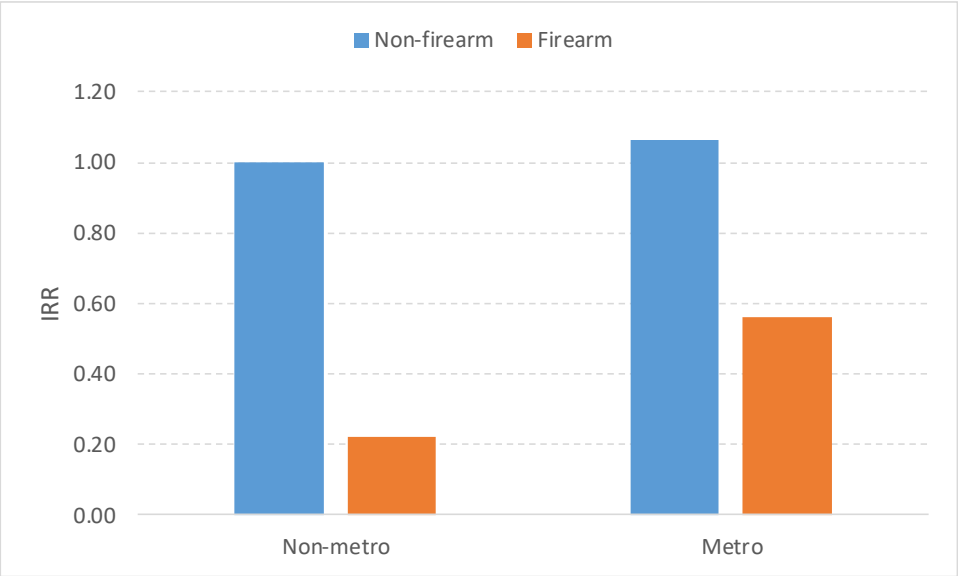

Figure 25. FA/NFA*M/NM interaction

7.4 Discussion

This chapter addressed objective 5 of this thesis "*to determine the explanatory variables for homicide in urban and rural areas*" using a set of generalized linear models which considered demographic factors, day of week, metro-/non-metro and firearm/non-firearm as *explanatory variables for* homicide. The estimated homicide rates were validated (Prinsloo et al., 2016) with the rates reported by the South African Police Service (SAPS) and proved credible, with the exception of the Northern Cape, for which the SAPS statistics have been criticised in the past for under reporting (Bruce, 2010; Gould et al., 2012). The remainder of this chapter's findings are discussed according to the three main hypotheses and relevant sub-hypotheses as stated in the beginning of this chapter.

Models 1-4 showed that the addition of age, sex and race did not alter the significantly higher relative risk for homicide in metro areas in the crude analysis by any great margin, indicating that they were not confounders for this relationship and that they were independent predictors of homicide in both metro and non-metro areas. This supports *Hypothesis 2* -that *age, sex and race are independently associated with homicide in metro and non-metro areas*. The higher relative risk for males compared to females is in keeping with the findings of the literature for low- and middle-income countries (WHO, 2014b). The higher relative risk for the 15-29 and 30-44 year age group is also consistent with the global literature that the 15-44 year age group has the

highest homicide rates (WHO, 2014b) and the age-specific rates in Table 11 of Chapter 5.

Having adjusted for M/NM areas, race, sex and age in Model 4, the relative risk for males was 4.6 times higher ($p<0.001$) than females. This was lower in comparison to the South African urban-biased 5-city analysis for 2001-2005 (Matzopoulos et al., 2014), where males had a 7.7 times higher risk than females. Trend data from 1994-2013 for homicide in Cape Town showed that males had a 8.5 times higher risk for homicide (Matzopoulos et al., 2018), indicating that the risk is higher when only urban/metro areas are included for analysis. Analysis of police robbery data from 2003 to 2014 (Bowman, Kramer, Salau, Kotze, & Matzopoulos, 2018) showed that females were more likely to be the victims of other forms of violence during robberies, which could partly be explained by the high rates of sexual violence for South Africa.

The IMS data analysed for this thesis, was the first national study in South Africa with adequate representation of race to determine the risk of homicide. Race was used in this study as a proxy for socio-economic status. The legacy of Apartheid still manifests in the form of income inequality and deprivation in South Africa, which have been associated with high rates of violence, particularly among the Black and Coloured population. The interaction effect in Model 5, where Coloureds had a higher risk of homicide than Blacks in metro areas, while the risk of homicide for Coloureds, Blacks and Asians were similar in non-metro areas, led to the rejection of s*ub-hypothesis 2.1*, that *Blacks are at greater risk in metro areas and Coloureds* are at greater risk in non-metro areas, which had been observed in the age-standardised rates by race in Table 13.

This is indeed a novel finding that informs previous inferences made on the risk of homicide by race –firstly that Coloureds had a greater risk of homicide than Blacks (Leggett, 2004a; Leggett, 2004b; Thomson, 2004), an analysis that did not take into account the overrepresentation of Coloureds in the data from a few selected mortuaries (Butchart, 2000; Butchart et al., 2001) at the time; and secondly, an analysis of 5-city urban-biased data that reported a greater risk of homicide for Blacks (Matzopoulos, 2012). This indicates the importance of having full national representation for race when assessing the risk of homicide. The findings of the generalized linear modelling for Model 5, of a higher homicide risk for Coloureds than Blacks in metro areas, as

opposed to a similar risk of homicide for Coloureds, Blacks and Asians in non-metro areas, should be deemed as superior to the age-standardised rates, as it was derived from more sophisticated analysis. In addition, the generalized linear model reflects the actual South African population, while the age-standardised rates make use of the World population age structure with equal proportions of males and females, which adjusts for skewness by age and sex of the South African population.

The age-specific rates in Figure 19 reflect different age patterns by race, sex and metro/non-metro, suggesting a mixture of epidemics for violence. The high peak in rates for Black and Coloured males in the 15-29 year age group in metro areas indicate that it may be driven by youth violence and gang-related violence. The sharp peak in the rates for the 30-44 and 45-59 year age group, for Coloured females in non-metro areas could be an indication of alcohol-related interpersonal violence. The peak for Asian males and females 15-29 years in non-metro areas could indicate that interpersonal violence occurs at a younger age for these groups. The increase in homicide in the 45-59 and 60+ age group for Whites, could possibly be the result of property-related robberies. With little metro/non-metro difference in the homicide rates for Whites across most age groups, the non-metro/rural peak for homicide in the 45-59 age group begs the question whether this could be associated with white farmer murders. The findings are indicative of the White and Asian population being better protected in terms of security in metro-areas compared to Blacks and Coloureds, while on the other hand in non-metro areas Whites and Asians are more sparsely distributed with fewer protective resources against homicide.

Concern has been raised in past media about farm attacks and farm murders against Whites (Wilkinson, 2017). The most recent reports pertain to 2017/2018 SAPS crime statistics, reporting 62 farm murders of which 46 were White farmers. The journalist only reports on the small proportion (0.3%) of deaths that this amounts to, suggesting that farmer murders are relatively insignificant in relation to the 20 336 annual murders. Had the author considered to calculate the rate of farmer murders relative to the 30 000 farmer population she quoted in her article, she would have realized that the White farmer murder rate is exceptionally high at 153 per 100 000 population. This rate is even higher than the 144 per 100 000 population homicide rate for 15-29 year old young Black urban males (Figure 19). The high transport-related

mortality rates for Whites in non-metro-areas however, appears to overshadow this. The findings does indicate a sense of vulnerability to homicide for the older White population in non-metro areas and should be of great concern.

Figure 20 for the sex*M/NM interaction in Model 6 indicated that there was no statistically significant difference in the higher risk for male homicide relative to female homicide in metro areas compared to the risk for male homicide relative to female homicide in non-metro areas, thus rejecting sub-hypothesis 2.2, that *the risk of homicide among males relative to the risk among females is greater in metro areas than in non-metro areas*. The higher homicide rates observed for metro areas are clearly driven by the distribution of males between metro and non-metro areas. The male homicide rate of 67.4 per 100 000 is four times higher than the global rate for males (WHO, 2014b); and nearly six times higher than the female homicide rate of 11.3 (Table 12 in Chapter 5) (Matzopoulos et al., 2015).

Day of week was used as proxy for alcohol consumption for this study and Model 7's findings indicated a significantly higher risk of homicide from Friday to Sunday, when alcohol consumption is known to be highest. This supported *Hypothesis 3*, that *day of week is independently associated with homicide*. Alcohol is a leading risk factor for death and disability globally (Gakidou et al., 2017) but South Africa does not have readily accessible data on alcohol-related deaths. The SAPS data however, have shown that the probability of co-occurring violence, such as homicide, assault, rape or other violent offences in the event of a robbery is higher over weekends (Bowman et al., 2018), while the mortuary data indicated a higher concentration of homicide over weekends consistent with the use of alcohol in some metropolitan cities (Matzopoulos, 2012).

The addition of the metro-/non-metro interaction with firearm-/non-firearm homicide in Figure 25 for Model 8 appeared to be the most influential predictor, causing the best improvement in the model fit. The effect modification noted by the higher risk for firearm homicide in metro areas than for non-metro areas supports the hypothesis that m*etro/non-metro differences for homicide can be explained by firearm use*. This is also supported by the firearm homicide rate in Table 25, which is 2.7 times

higher in metro areas than non-metro areas. The analysis confirms that use of a firearm is one of the factors that drive the higher rates for homicide in metro areas.

The age-specific homicide rates by race indicated that the difference in homicide rates were largest in the 30-44 year age group for the different race groups. Globally, across the world, the highest homicide rates were also in the 15-29 and 30-44 year age group. The respective rates of 10.9 and 9.3 per 100 000 globally (WHO, 2014b) makes South Africa's age-specific homicide rates 5.4 and 6.6 times higher for these age groups.

The distinct peak in firearm homicide rates for Coloureds and equally high rates for Blacks 15-29 years (Figure 24a) could be an indication of gang-related violence particularly in the Western Cape, as five of the top ten suburbs nationally for multiple murders during one incident were from the Western Cape (SAPS, 2016a). Matzopoulos et al. (2018) confirmed with trend analysis for Cape Town that homicide rates among youth and young adults 15-29 years were significantly higher than adults aged 30-44 years. The Black and Asian race groups both peaked in the 30-44 year age group for firearm homicide (Figure 24a), while Whites peaked in the older ages. This may indicate that the motive of the firearm homicide differed by age and race group.

The 2009 IMS indicated high firearm homicide rates for KwaZulu-Natal and Gauteng (Figure 22). Police data show that during the 2009/2010 financial reporting period, KwaZulu-Natal and Gauteng had the highest number of illegal firearms reported. Gauteng had more than 4100 illegal firearms reported annually and KwaZulu-Natal had approximately 4900, which was exceptionally high in comparison to the Western Cape in third place with nearly 2200 illegal firearms reported by SAPS for 2009/2010. It appears that this trend continues according to current police reports for illegal firearms (SAPS, 2014). Concern was raised recently over the number of firearms stolen from police armouries, particularly in KwaZulu-Natal and how it fuelled taxi violence and political killings in the province (Dolley, 2017). Higher firearm homicide rates for the two major cities of Gauteng and KwaZulu-Natal (Johannesburg and Durban) were also reported by Matzopoulos et al. (2014) from 2001-2005, in comparison to Cape Town, Port Elizabeth and Pretoria. An evaluation of routine verbal autopsy data for homicide in a rural district of northern KwaZulu-

Natal, from 2000-2008 found the use of firearms to be the leading cause (65%) of homicide, with the highest rates among those 25-34 years (Otieno et al., 2015).

The city of Cape Town have seen increasing rates of firearm homicide since 2010. This was linked to an ex-police officer who was eventually convicted (Petersen, 2016) for selling illegal firearms to gangs in the city (Dolley, 2014; Baadjies, 2015). The literature review in Chapter 2 discussed the effects that the distribution of these illegal firearms to gangs had on communities in Cape Town between 2010-2016 (Gun Free South Africa, 2017). Illegal firearms (Abrahams & Jewkes, 2005) and the trading of illegal drugs by gangs within communities (Goga, 2014) have been identified as risk factors for violence. These gangs are often more organised than street gangs and can be more difficult to trace and curb. Bowman et al. (2018) identified that firearms were used in 41.9% of South African robberies reported to SAPS.

The literature highlights the community and societal risks of firearm homicide and the detrimental effect that firearm availability has on communities. Earlier studies showed the importance of firearm control legislation and how the Firearms Control Act (No. 60 of 2000) (Firearms Control Act, 2004) contributed to the reduction in homicide rates in South Africa (Abrahams et al., 2013; Matzopoulos et al., 2014; Matzopoulos et al., 2016; Matzopoulos et al., 2018). The 5-city trend analysis by Matzopoulos et al. (2014) found that 4585 lives were saved between 2001-2005 with the implementation of the FCA. For the 1994-2013 trend analysis of homicide in Cape Town, Matzopoulos et al. (2018) attributed the bulk of the excess mortality to the increased exposure of illegal firearms. Table 27 lists the availability of firearms in South Africa and specifically in Cape Town, through mismanagement of the safe storage or destruction of firearms and weapons from the South African National Defence Force (SANDF), recovery of stolen weapons and the loss of weapons by the SAPS and the relaxation and enforcement of gun laws from 1994-2013. Factors that contribute to increased levels of violence and strategies to reduce violence will be reflected on in the Conclusion.

Table 27. Summary of firearm availability in Cape Town and South Africa, from 1994 to 2013

1994-2000*	**Increasing firearm availability** from new licenses, caches from previous conflicts leeching into circulation, along with inadequately secured state-owned weapons from various state departments and the security forces of former apartheid *bantustans* (self-governing rural states typically situated in remote marginally agricultural land).
• In 1996 the South African National Defence Force (SANDF) stockpiled 'war reserves' comprising 450 000 rifles, 17 000 pistols, and thousands of machine guns (Gould, Lamb, Mthembu-Salter, Nakana, & Rubel, 2004) • Theft of SANDF weapons peaked with 311 weapons stolen in 1998 (Gould et al., 2004) • The SANDF destroyed 262 667 surplus weapons between 1998 and 2001 (Gould et al., 2004) • The approval rate for new license applications among civilians was extremely high. More than 1.1 million new licenses were granted from 1994 to 2000, an average of 180 166 per annum (Central Firearms Registry, 2014) • By mid 1999 it was estimated that civilians owned 4.5 million firearms (Gould et al., 2004) • A firearm amnesty in 1994 and 1995 recovered only 900 weapons and 7 000 rounds of ammunition (Kirsten, 2008) • Relatively few confiscated and obsolete non-military state firearms (12 416) were destroyed in 1999 (Meek & Stott, 2003)	
2001-2002*	**Plateauing firearm availability** with the adoption of the Firearms Control Act of 2000 (FCA), including more restrictive licensing and destruction of surplus weapons
• The Firearms Control Act, 2000 (Act No. 60 of 2000) was assented to in April 2001 (Firearms Control Act, 2004) • Theft of South African National Defence Force weapons averaged 96 per annum over the two year period (Gould et al., 2004) • The rate of new civilian license applications approved dropped by 21% to an average of 143 157 annually (Central Firearms Registry, 2014) • Special operations by the police recovered 21 027 unregistered firearms in 2002, a similar number to the 22 120 firearms reported lost or stolen in that year (Meek & Stott, 2004) • In 2002 the police received additional human and physical resources to implement the FCA and appointed designated firearm officials (Gould et al., 2004) • Destruction of confiscated and obsolete state firearms increased to 30 023 in 2001 and 58 617 in 2002 (Gould et al., 2004)	
2003-2010*	**Decreasing firearm availability in the general population** as the provisions of the FCA come into effect, including amnesties, audit of state owned firearms, recovery operations, destruction of surplus weapons and confiscated weapons more restrictive licensing
• The police conducted an audit of state-owned firearms in 2003 (Meek & Stott, 2003) • The recovery of stolen and unregistered firearms increased through special operations such as Operation Sethunya. In 2003, 35 481 firearms and >1.5 million rounds of ammunition were recovered, which surpassed the 20 164 firearms reported stolen (Meek & Stott, 2004)	

• The police conducted wide-scale background checks for compliance with the FCA safety requirements among legal firearm owners from 2003 with a particular focus on owners with five or more weapons (Meek & Stott, 2004) • Stricter assessment of new firearm license applicants commenced in April 2003 at which time there was a reported 70% refusal rate for new applications (Ellis, 2003) • The rate of new civilian license applications approved dropped to 25 234 per annum between 2003 and 2010 (Central Firearms Registry, 2014) • The Firearm Control Regulations pertaining to the FCA were published in March 2004 (Firearms Control Act, 2004) • Firearm amnesties recovered 98 412 weapons in 2004 and 2005 (Kirsten, 2007) and 32 169 weapons in 2009 and 2010 (SAPS, 2016b) • Destruction of confiscated and obsolete state firearms increased to 87 097 in 2003 (Meek & Stott, 2003)
2007-2013 **Increasing firearm availability in the Coloured population** through criminal gangs illegally obtaining weapons earmarked for destruction
• Firearm licenses and firearms marked for destruction were fraudulently issued to Cape Town criminals by corrupt police officials and gun dealerships. More than 2400 firearms were sold to Cape Town gang leaders between 2007 and 2014 (Dolley, 2014; Baadjies, 2015; Serrao, 2015; Petersen, 2016; Thamm, 2016)
2011-2013 **Increasing firearm availability in the general population** with less stringent application of the FCA provisions and increased licensing
• The head of Central Firearms Registry (CFR) was suspended and then demoted in 2010 as part of Minister of Police, Mr Nathi Mthethwa's internal review (De Clercq, 2011) • As per the Minister's instruction, the police cleared the CFR backlog and finalised more than 1 million firearm applications including license renewals and new licenses (SAPS, 2011, 2012) • The approval rate for new licenses increased to an average of 88 842 per annum between 2011 and 2013 (Central Firearms Registry, 2014) *These shifts in firearm availability are largely consistent with an independent estimate for the number of registered firearms from 1994 to 2011 (Alpers, Rossetti, & Wilson, 2017)

Source: Matzopoulos et al. (2018)

8 CONCLUSION AND RECOMMENDATIONS

Prior to the Injury Mortality Survey (IMS), there was no nationally representative study on injury deaths, with detail on the manner of death by age, sex and race for urban- and rural areas. The aim of this thesis was to utilise national data for injury mortality in South Africa, in order to conduct advanced statistical analyses to identify urban-rural differences for injury deaths, which has never been done before for South Africa.

In summary, the following main findings according to each of the five objectives were noted:

Objective 1: *To review available literature on injury mortality and associated risk factors for homicide,* was addressed showing higher rates of injury mortality in rural areas for high-income countries, known to be driven by the high transport mortality rates. The literature review also identified a known list of risk variables for the injury mortality profile.

Objective 2: *To conduct a situational analysis of injury data sources in South Africa*, identified persisting flaws in the country's vital registration system through the misclassification of injury deaths in particular, resulting in a skewed picture of the injury mortality profile. Mortuary-based surveillance systems were urban-biased and were proven to be unsustainable. This identified the need for a nationally representative survey on injury deaths, resulting in the IMS, which was utilised for this thesis.

Objective 3: *To evaluate the quality of the survey data used for this thesis,* was done using the data quality framework of Rao et al. (2005), assessing the IMS data for its generalizability/representativeness, reliability, content validity and policy relevance, using basic analysis of proportions by manner of death, age, sex, race and metro/non-metro area; and comparisons with other mortality data sources such as SAPS homicide data and national vital registration data. The results formally showed

that the IMS, derived from mortuary-based forensic pathology data, is indeed superior to South African vital registration data.

Objective 4: *To characterize the variables driving the urban-rural differences of fatal injuries in South Africa*, showed through a basic analysis of the proportions, that there are metro/non-metro differences for the injury mortality profiles, and the age-specific and age-standardised rates identified that the metro/non-metro differences were possibly driven by the high homicide rate for metro-areas.

To further investigate the injury mortality differences by metro- and non-metro area, the MCA was firstly used for exploratory purposes, to identify any associations for outcome variables with multiple response categories. However, the low percentage variance for the MCA indicated that this method could not provide enough insight to likely associations and that further statistical modelling is required.

Multinomial logistic regression modelling, as a more sophisticated approach to the MCA then tested Hypothesis 1: *Homicide is higher in metro areas than non-metro areas; suicide and transport-related deaths are higher in non-metro areas, while other unintentional is similar for metro- and non-metro areas*. The findings highlighted a significantly higher likelihood for homicide in metro areas compared to non-metro areas, while transport-related deaths were significantly lower in metro areas with no metro/non-metro difference for suicide, thus supporting Hypothesis 1.

The predicted proportions calculated from a multinomial linear regression model (model 7) with a race*age and race*M/NM interaction found males had a significantly higher likelihood for homicide than females, with no difference between male and female transport-related deaths. The association between other unintentional and 0-14 years noted in the MCA was confirmed by the MLR analysis, and that it was highest for Coloured and Black children. Whites between 30-59 years had a higher likelihood for suicide compared to the other race groups, while Whites were second to Blacks for the highest likelihood of a transport-related death in the 45-59 year age group. The predicted proportions also identified that Whites and Asians 15-29 years had the highest likelihood for transport-related deaths. Coloureds and Blacks 15-44 years had a significantly higher likelihood for homicide relative to other unintentional injury

deaths. Associations were also noted for White, Asian and Black transport-related deaths in non-metro areas and for homicide among Blacks and Coloureds in metro areas, but for non-metro areas the likelihood for homicide was higher for Coloureds than Blacks. As homicide was identified to be the driver of the metro/non-metro differences for the injury mortality profile, it was explored in greater detail through objective 5.

Objective 5: To determine the explanatory variables for homicide in urban- and rural areas, was addressed through negative binomial regression, using generalized linear modelling. It included the population at risk and considered the following hypotheses:

Hypothesis 2: *Age, sex and race are independently associated with homicide in both metro- and non-metro areas*, tested for independence in a model to adjust for possible confounding, with homicide rate as the dependent variable and M/NM as explanatory variable, then adding each of age, sex and race separately to show independence. This was done in Models 1-4, finding a significantly higher relative risk for homicide in metro areas, and that no confounding was evident, thus supporting hypothesis 2.

Sub-hypothesis 2.1: *Blacks experience a higher risk for homicide in metro areas than Coloureds; and Coloureds experience a higher risk for homicide in non-metro areas than Blacks*, showed that there is effect modification by race in Model 5. The model found a higher homicide risk for Coloureds than Blacks in metro areas, and a similar risk of homicide for Coloureds, Blacks and Asians in non-metro areas, thus rejecting sub-hypothesis 2.1. As discussed in Chapter 7, this was different to the findings for the age-standardised homicide rate where Blacks had a higher metro-area homicide rate than Coloureds. This is because the age-standardised rates use the World population age structure with equal proportions of males and females, while the model reflects the actual skewed population by age and sex for South Africa. The findings of the more sophisticated modelling are superior to the age-standardised rates, confirming that the risk of homicide for Coloureds are higher than Blacks in metro areas and that Blacks, Coloureds and Asians have a similar risk of homicide in non-metro areas. This partly confirms the finding by Leggett (2004b) that Coloureds have a higher risk of

homicide than Blacks, although the author's finding was based on urban-area mortuary data with an over representation of Coloureds.

Sub-hypothesis 2.2: *The risk of homicide among males relative to the risk among females is greater in metro areas than in non-metro areas*, was investigated by the sex*M/NM interaction in Model 6. This showed that the higher risk for male homicide relative to female homicide in metro areas was not significantly different from the higher risk for male homicide relative to female homicide in non-metro areas, thus rejecting sub-hypothesis 2.2.

Hypothesis 3: *Day of week is independently associated with homicide,* was tested in model 7 and found a significantly higher risk of homicide over weekends. The addition of day of week did not alter the remaining explanatory variables by any great margin, indicating that confounding was not evident and that hypothesis 3 was upheld.

Hypothesis 4: *Metro/non-metro differences for homicide can be explained by firearm use***,** showed a significant interaction between firearm homicide and metro/non-metro, indicating effect modification in model 8. Firearm homicide in metro areas is 2.6 times higher than for non-metro areas, with no difference in non-firearm homicide between metro- and non-metro areas, thus supporting hypothesis 4.

8.1 Study strengths and contribution to knowledge

The data utilised in this study is representative of both rural and urban areas in South Africa. It allowed for cross-validation with SAPS data (Prinsloo et al., 2016) and identified extensive misclassification of injuries in vital registration data (Prinsloo et al., 2017). The survey data has greater reliability for national estimates of injury mortality, and the estimates are better than Global Burden of Disease estimates, which have previously under-estimated homicide and road traffic deaths (Matzopoulos et al., 2015; Pillay-van Wyk et al., 2016a). The age-standardised rates can usefully contribute to monitoring South Africa's progress towards achieving the 2030 Sustainable Development Goals (SDGs) to reduce injury and violence (United Nations, 2015; WHO, 2016b).

This study's most significant knowledge contribution includes the identification of metro/non-metro as a significant predictor of the injury mortality profile in South Africa. The association of metro/non-metro differences in the pattern of homicide for Blacks and Coloureds, also resolved conflicting statements found in the literature regarding race and homicide in South Africa. This highlights the importance of adequate representation of race, and injury data from urban and rural areas for policy formulation.

8.2 Limitations

It is acknowledged that the 2009 IMS data might be considered outdated. However, no other nationally representative study has been conducted since. In addition, the 2009 IMS study had to be conducted in 2011, using data from two years prior, to ensure that most police investigations and court cases pertaining to non-natural deaths were finalized at the time of data collection. Even though the 2009 IMS homicide rate was not that different to the SAPS data derived rate, as discussed in section 5.3.1, no other nationally representative sources of data are available to compare the rates for suicide, transport-related deaths and other unintentional injuries. This was therefore the only reliable data source that could be used to inform the more sophisticated multinomial modelling in Chapter 6 and generalized linear modelling for homicide in Chapter 7.

Efforts to request blood alcohol concentration data from forensic pathology laboratories for deaths that occurred in 2009 were not successful. Day of week was used as proxy for alcohol consumption, with the assumption that more drinking occurred over weekends.

As the sampling was stratified by mortuary size and metro-/non-metro area, province could not be included as one of the explanatory variables for homicide in the regression modelling. A comparison with the SAPS homicide data identified possible under-sampling by the IMS for Mpumalanga, but overall the homicide estimates utilised in this study were still significantly higher than SAPS (Matzopoulos et al., 2015). Race was generally useful as a proxy for socio-economic status to identify high-risk groups and will likely become less valid over time. Rates for the older Asian population were unstable due to the low data counts.

Another limitation was that no nationally representative non-fatal injury data were available for inclusion in this study. The challenges towards establishing a non-fatal injury surveillance system were discussed in section 2.7.2 of this thesis.

A limitation of the transport-related mortality rates, is that using a denominator of 100 000 population for transport-related deaths will generally not provide an accurate profile of the population at risk, as not the entire population will be exposed to the same risk at the same time (Chokotho, Matzopoulos, & Myers, 2012b) and instead the driver population is required.

Lastly, there is limited information available on access to firearms in South Africa. Hence, for this analysis the term "firearm use" was preferred in formulating hypothesis 4, in relation to firearm as the manner of homicide death.

Taking into account the strengths and limitations of this study, the next section introduces a set of recommendations based on the main findings which have the most public health relevance.

8.3 Recommendations

Chapter 1 discussed the importance of keeping track of the injury mortality rates for South Africa, as they can inform the 2030 Sustainable Development Goals (SDGs) for reducing injury and violence (United Nations, 2015). The World Health Organization (WHO) expressed the need for country-specific statistics disaggregated by age, sex, race, ethnicity, migratory status and other characteristics to track disadvantaged populations within countries; and to facilitate the global comparison of injury statistics (WHO, 2016b).

As reliable injury mortality rates for South Africa are not easily attainable, the results add value and inform South Africa's contribution to monitoring SDGs for injuries and violence; and inform government and public health actors about the magnitude and public health relevance of particular variables associated with injury and violence. The high homicide and transport-related mortality rates for South Africa indicates a need for urgent intervention in order to achieve the SDGs by 2030. In particular, the SDGs related to:

- *Target 3.6: "by 2020, halve the number of global deaths and injuries from road traffic accidents"*
- *Target 5.2: "eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation"*
- *Target 16.1: to "significantly reduce all forms of violence and related death rates everywhere"*

8.3.1 Recommendations for reducing transport-related deaths

The transport mortality rate was nearly the same magnitude as homicide for this study, and trend estimates indicate it remained constant between 1997 and 2012, while homicide has declined (Msemburi et al., 2016; Pillay-van Wyk et al., 2016b). Hence, current strategies to reduce transport-related deaths are clearly not working. The higher relative risk for transport-related deaths, relative to other unintentional for Asians and Whites 15-29 years warrants the attention of policy-makers. This could be the result of a higher number of motor vehicle drivers and motor cycle drivers, and higher automobile ownership in Asian and White communities for the young driver population.

The young driver population in South Africa could benefit from a Graduated Drivers Licensing (GDL) system. Evidence from GDL systems in New Zealand, United States and Australia indicate that it reduces the risk of a fatal crash or serious injury (Bates et al., 2014). This system gradually increases a new driver's exposure to complex driving situations in a safe manner. The first phase of a GDL system involves a *learner phase*, which allow new drivers some practical driving experience under supervision in a lower risk situation. The *provisional license* phase limits the exposure to risky situations, such as restrictions to driving at night, driving with passengers, after alcohol intake, the use of mobile phones and vehicle power restrictions. An exit test is required before a new driver is granted a full, *open phase* license. South Africa's current licensing system consist of the *learner phase* and full, *open license phase,* and could benefit from applying the restrictions noted in the provisional phase of a GDL system.

Existing interventions such as drink driving campaigns should be enforced, in both low- and high-income areas. The use of helmets for motor cycle drivers should

be enforced, as well as penalties for any risky driving behaviour. The results of this thesis also indicate that interventions should target road design, speed limits- and seat-belt enforcement, and access to post-crash medical care on rural area roads, as suggested by the World Health Organization (Peden, 2005). Pedestrians and cyclists contribute to a large proportion of road crash victims in low- and middle-income countries. Policies should therefore not only centre on motorized travel but should also provide equal protection for all road users and socio-economic groups, by addressing human behaviour, the environment and traffic law enforcement (Peden, 2004).

This all relates to Haddon's matrix (Haddon, 1968), which incorporates human, vehicle and environment factors during the pre-crash, crash and post-crash phase (Figure 2) and the systems approach (CDC, 1999) needed to reduce risk exposure, to prevent the occurrence of road traffic crashes, and to reduce the severity of an injury and the consequences of injury by improving post-crash care. These have been highlighted as existing challenges for road safety policy-makers (Peden, 2004). Integrating such an approach will require collaboration between the Department of Health (DoH) and the Department of Transport (DoT) and other agencies across private sectors and spheres of government. Such intersectoral partnerships are essential to establish sustainable upstream interventions such as infrastructural improvements. It is recommended that this be prioritised ahead of downstream interventions that target behaviour change in road users (Matzopoulos et al., 2008).

8.3.2 Recommendations for reducing childhood other unintentional injury deaths

The significantly higher other unintentional injury mortality rate for children 0-4 years in metro areas, is another finding not previously noted among the exceptionally high homicide and transport mortality rates of South Africa. The prevention of childhood injuries have not been included in national health priority lists (van As & van Niekerk, 2017), as the prevention of HIV/AIDS and other communicable diseases always takes precedence. Yet, it warrants the attention of policy makers, as this age group is unable to self-protect against injury or death. Interventions are required within communities and day-care centres to alert parents and caregivers of possible risks. Existing hospital databases should be analysed to determine whether the leading causes of other unintentional injury are similar to the causes of death and to identify target communities for intervention. Disability as a result of injuries sustained during

childhood can have a detrimental effect on the injured child, the health system and the economy. Other unintentional injuries require intervention to prevent yet another escalation of a public health problem in South Africa.

8.3.3 Recommendations for reducing homicide

The higher homicide risk for Coloureds compared to Blacks in metro areas and the significant interaction between firearms and metro/non-metro, which highlighted firearms as one of the drivers of the higher homicide rates in metro areas, calls for urgent intervention. The impact of the Firearms Control Act (Firearms Control Act, 2004), firearm availability and illegal firearms on homicide rates have been demonstrated by earlier studies (Abrahams et al., 2013; Matzopoulos et al., 2014; Matzopoulos et al., 2018) and reiterated throughout this thesis. Reclaiming of illegal firearms should be targeted for Gauteng, KwaZulu-Natal and the Western Cape in particular, as SAPS data indicate that these are the leading provinces for possession of illegal firearms (SAPS, 2014). Restrictive firearm licensing, purchase policies and enforced bans on carrying firearms in public are evidence-based measures to prevent youth violence (WHO, 2010c).

The prevention of non-firearm homicide can only be addressed through interventions that will impact broader society towards the prevention of violence. This will require government to increase their funding towards social protection for low-income communities. Security for old age, disability, housing and unemployment in particular (Rogers & Pridemore, 2013) will help overcome the effects of inequality within society. WHO (2010c) provides strong evidence that developing life skills in children and adolescents prevent youth violence. The findings of this study however, did show a significantly higher risk of homicide for the 30-44 year age group. Homicide risk was also significantly higher over weekends, indicating that factors such as unemployment and alcohol were more likely to have influenced the homicide rates. A review of the literature in Chapter 2 indicated that the majority of alcohol-attributable deaths in South Africa occurred among the lower socio-economic status group (Probst et al., 2018). Emerging evidence indicate that the regulation of alcohol sales and raising alcohol prices prevents all forms of violence, while improving drinking environments prevent youth violence (WHO, 2010c). Attempts to amend South African policies on the sale, use and advertising of alcohol have however, been

met with strong resistance from the liquor industry (Parry et al., 2012; Parry et al., 2014).

Krisch et al (2015) suggested that violence can be reduced by investing in urban planning and targeting hotspots through urban upgrading of fast growing cities that are most vulnerable to violence. Violence Prevention through Urban Upgrading (VPUU) was implemented in communities in the Western Cape, South Africa and involved the modification and upgrading of public spaces and the monitoring of liquor outlets (Matzopoulos & Myers, 2014). An evaluation of health facility data for two VPUU informal settlement communities found that living in a VPUU intervention area was protective against the presentation of a violent injury at hospital when controlling for other risk factors (Trupe, 2016). Eisner (2015) suggests though, that effective rule of law, based on legitimate law enforcement, the protection of victims, swift and impartial judgement, moderate punishment and humane prison conditions is key to sustained violence reduction. This study's findings for homicide highlights the extent of this important public health problem in South Africa, in that the individual, relationship, community and societal factors for homicide are interweaved, and that structured interventions to reduce homicide should bear this in mind.

8.3.4 Recommendations for future data sources and strengthening of existing data

Further studies on injury mortality data are required on a regular basis to monitor trends. The 2009 IMS can be enhanced in future studies by improving the geographic granularity of the data, by including detail on the injury setting and rural distinction within metropolitan areas; the motive of intentional injuries and the linking of alcohol data to death records. This will require linking of data sources between forensic pathology, police and forensic chemistry laboratories. A nationally representative survey of such magnitude can be quite costly and will require support and resources from government or private funding sources. The implementation of surveillance systems will also involve similar challenges. While surveys can be completed at a particular time slice, it will be much more difficult to sustain ongoing surveillance systems. Surveys are therefore more likely to be more accurate and complete compared to surveillance systems in the South African setting.

Better quality data are required for optimal resource allocation to high-risk groups. Strengthening of Stats SA data will require a change in the death notification form to include specification of the manner of death. Training of doctors in medical

certification is also important, as well as the complete registration of deaths. This will reduce the proportion of misclassified deaths within vital registration data. Improving the reliability of vital registration data could reduce the need for the implementation of costly surveys or surveillance systems.

The SAPS data should be available to research or academic institutions on a regular basis, to validate the SAPS statistics with available alternative data sources. Collaboration between SAPS and academic institutions will ensure the implementation of strategic, evidence-based intervention strategies targeted at high-risk areas.

The finding that Whites and Asians are at greater risk of homicide in non-metro areas identifies the need for a future study to investigate the extent of farm murders. This should be representative of all race groups and include both farm employers and employees.

Studies on non-fatal injuries are required, in particular hospital-based cross-sectional studies, using structured validated questionnaires and medical records. This could provide in-depth information on the likely perpetrators and the motives behind violent attacks of injured victims, the nature of physical injuries sustained such as fractures and spinal cord injuries, and a follow-up study could provide information on the duration of disability. This could shed light on the effects of violence and the magnitude of intimate partner violence and child abuse, which are not readily available via mortality data sources. It can also provide detail on sexual violence, gang-related incidents and other motives of violence.

8.4 Concluding remarks

In conclusion, this thesis presented novel findings related to a comparison between metro- and non-metro areas and addressed gaps in the literature, such as the dearth of information about the patterns of metro/non-metro differences for injury deaths. It also addressed the lack of information on the predictors of homicide risk and differences by race, as previous studies did not have adequate representation for race and metro-/non-metro areas when assessing homicide risk, or did not conduct multivariate analysis for the joint effects of relevant explanatory variables driving injury mortality. It highlighted associations by age and race for metro- and non-metro area transport-related deaths, not previously identified in the literature. The findings of this study have facilitated specific recommendations for targeted interventions to reduce the magnitude of injuries and violence in South Africa.

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APPENDIX I

Injury Mortality Survey

A UNIQUE STUDY RECORD NUMBER SHOULD BE CREATED AS THE DATA UPLOADS TO THE CENTRAL DATABASE

1 **What data entry is this?** Initial | 20th record 2 **Fieldworker code** ☐☐

IF "20th record" THEN ALLOW DUPLICATES FOR FIELD 4 "DR NO" AND FIELD 22 "BI-1663"
THIS SHOULD BE LINKED TO MORTUARY CODE

3 **Mortuary code** ☐☐ 4 **DR No.** ☐☐☐☐☐☐☐

5 **Record**
- ☐ Found
- ☐ Missing PM
- ☐ Missing folder → EXIT AFTER 11
- ☐ Storage → EXIT AFTER 11

6 **Date of death** d d m m yy yy

7 **Date of birth** d d m m yy yy
AUTOMATICALLY CALCULATE AGE: 109 CUT-OFF
IF NO D.O.B *skip* to Estimated Age

8 **Estimated Age** y y y m m
999 IF UNKNOWN, NO CUT-OFF

9 **Sex** M | F | U

10 **Population group** B | C | A | W | U

11 **Cause of death**
- ☐ Non-natural PROCEED TO 12
- ☐ Natural EXIT
- ☐ Foetus EXIT
- ☐ Undetermined PROCEED TO 12

12 **Apparent manner of death (if Non-natural)**
- ☐ Homicide → *skip* 13
- ☐ Suicide → *skip* 14
- ☐ Transport → *skip* 15
- ☐ Other Unintentional → *skip* 16
- ☐ Undetermined → *skip* 17

13 **Circumstances of injury (if Homicide)**
- ☐ Firearm Discharge
- ☐ Sharp force (cut / stabbed)
- ☐ Blunt force (beaten with object, punched or kicked)
- ☐ Strangled/Asphyxiated/Suffocated
- ☐ Poison, ingestion
- ☐ Poison, gassing
- ☐ Fire /other burn
- ☐ Abandoned baby (if <1YEAR)
- ☐ Pushed from height
- ☐ Crushing
- ☐ Electrocution
- ☐ Drowning, immersion
- ☐ Explosive blast
- ☐ Other _____
- ☐ Unknown

skip → 18a

14 **Circumstances of injury (if Suicide)**
- ☐ Firearm Discharge
- ☐ Sharp force (cut / slit)
- ☐ Hanging
- ☐ Poison, ingestion (e.g. overdose)
- ☐ Poison, gassing (e.g. exhaust)
- ☐ Fire /other burn
- ☐ Jumped from height
- ☐ Railway pedestrian
- ☐ Other _____
- ☐ Unknown

skip → 18a

15 **Circumstances of injury (if Transport)**

- ☐ MV Pedestrian
- ☐ MV Passenger
- ☐ MV Driver
- ☐ MV Unspecified
- ☐ Motor-cycle Driver
- ☐ Motor-cycle Passenger
- ☐ Bicycle
- ☐ Railway pedestrian
- ☐ Railway passenger
- ☐ Aviation casualty
- ☐ Other _____
- ☐ Unknown

skip → 18a

16 **Circumstances of injury (if Other Unintentional)**

- ☐ Firearm Discharge
- ☐ Sharp force (cut)
- ☐ Blunt force
- ☐ Asphyxiated / Suffocated
- ☐ Poison, ingestion (e.g. overdose)
- ☐ Poison, gassing (e.g. exhaust)
- ☐ Fire /other burn
- ☐ Fall
- ☐ Crushing
- ☐ Drowning, immersion
- ☐ Animal contact (e.g. dog bite)
- ☐ Machinery (e.g. farm/recreational)
- ☐ Lightning
- ☐ Natural/Environmental factors
- ☐ Electrocution
- ☐ Explosive blast
- ☐ Circumcision
- ☐ Surgical/Medical Misadventure
- ☐ Other _____
- ☐ Unknown

skip → 18a

17 **Circumstances of injury (if Undetermined)**

- ☐ Firearm Discharge
- ☐ Sharp force
- ☐ Blunt force
- ☐ Asphyxiated / strangled
- ☐ Hanging
- ☐ Poison, ingestion
- ☐ Poison, gassing
- ☐ Fire /other burn
- ☐ Fall/push/jump
- ☐ Drowning, immersion
- ☐ Abandoned baby
- ☐ MV Pedestrian
- ☐ MV Passenger
- ☐ MV Driver
- ☐ MV Unspecified
- ☐ Motor-cycle Driver
- ☐ Motor-cycle Passenger
- ☐ Bicycle
- ☐ Railway pedestrian
- ☐ Railway passenger
- ☐ Aviation casualty
- ☐ Animal contact (e.g. dog bite)
- ☐ Machinery (e.g. farm/recreational)
- ☐ Crushing
- ☐ Lightning
- ☐ Natural/Environmental factors
- ☐ Electrocution
- ☐ Explosive blast
- ☐ Circumcision
- ☐ Surgical/Medical Misadventure
- ☐ Other _____
- ☐ Unknown

18a Was the injury **work-related**? [Y] [N] [U]

skip if No/Unknown ↓ 19

18b Was the injury related to **Mining?** [Y] [N] [U]

19 Was the **"Sexual Assault Kit"** used? [Y] [N] [U]

20 Was the death in custody (police, prison etc): [Y] [N] [U]

21 **Blood Alcohol level** [0] [.] [ ] [ ] [ ] g/100ml

22 **BI-1663** [A] [O] [ ] [ ] [ ] [ ] [ ] [ ] [ ] ALLOW DUPLICATE IF FIELD 1="20th record"
OTHERWISE MUST BE UNIQUE NUMBER

NOTE: EVERY 20TH RECORD/FOLDER SHOULD BE FLAGGED TO PUT ASIDE FOR DOUBLE DATA ENTRY BY A 2ND FIELDWORKER

Figure I. Injury Mortality Survey data collection form

Table I. Injury deaths by manner of death and province, 2009 (N= 50 394)

	Homicide N (%)	Suicide N (%)	Transport N (%)	Other unintentional N (%)	Total N (%)
Eastern Cape	3 458 (46.8)	861 (11.7)	2 011 (27.2)	1 057 (14.3)	7 387 (100.0)
Free State	970 (32.2)	395 (13.1)	1 180 (39.2)	468 (15.5)	3 013 (100.0)
Gauteng	4 436 (37.2)	1 656 (13.9)	4 236 (35.5)	1 611 (13.5)	11 939 (100.0)
KwaZulu-Natal	4 779 (45.0)	1 354 (12.7)	3 129 (29.4)	1 365 (12.9)	10 627 (100.0)
Limpopo	860 (24.9)	410 (11.8)	1 790 (51.7)	402 (11.6)	3 462 (100.0)
Mpumalanga	668 (20.9)	339 (10.6)	1 875 (58.6)	318 (9.9)	3 200 (100.0)
North West	829 (24.9)	577 (17.3)	1 413 (42.4)	512 (15.4)	3 331 (100.0)
Northern Cape	607 (39.9)	197 (12.9)	483 (31.8)	235 (15.4)	1 521 (100.0)
Western Cape	2 422 (40.9)	683 (11.5)	1 627 (27.5)	1 184 (20.0)	5 916 (100.0)
Total	19 028 (37.8)	6 471 (12.8)	17 742 (35.2)	7 153 (14.2)	50 394 (100.0)

Table II. Distribution of SA population, by population group and Metro/Non-metro area, 2009 (N= 50 150 354)

Province	BM	BNM	CM	CNM	AM	ANM	WM	WNM
Eastern Cape	1 316 298	4 287 270	304 889	216 866	17 716	8 186	227 139	87 631
Free State		2 409 335		81 936		9 410		249 873
Gauteng	8 870 242		405 716		330 879		1 913 468	
KwaZulu-Natal	2 484 853	6 275 741	84 487	54 669	577 285	185 285	231 431	203 070
Limpopo		4 960 830		14 305		15 452		136 383
Mpumalanga		3 701 855		35 705		23 439		292 819
North West		2 981 696		66 645		16 249		255 640
Northern Cape		633 525		448 451		7 946		88 693
Western Cape	1 408 130	456 121	1 547 174	1 227 907	51 260	8 924	600 155	337 375
Total	14 079 523	25 706 373	2 342 266	2 146 484	977 140	274 891	2 972 193	1 651 484

BM= Black Metro; **BNM**= Black Non-metro; **CM**= Coloured Metro; **CNM**= Coloured Non-metro; **AM**= Asian Metro; **ANM**= Asian Non-metro; **WM**= White Metro; **WNM**= White Non-metro

Table III. Distribution of SA population, by population group, 2009 (N= 50 150 354)

Province	Black	Coloured	Asian	White	Total
Eastern Cape	5 603 568	521 755	25 902	314 770	6 465 995
Free State	2 409 335	81 936	9 410	249 873	2 750 554
Gauteng	8 870 242	405 716	330 879	1 913 468	11 520 305
KwaZulu-Natal	8 760 594	139 156	762 570	434 501	10 096 821
Limpopo	4 960 830	14 305	15 452	136 383	5 126 970
Mpumalanga	3 701 855	35 705	23 439	292 819	4 053 818
North West	2 981 696	66 645	16 249	255 640	3 320 230
Northern Cape	633 525	448 451	7 946	88 693	1 178 615
Western Cape	1 864 251	2 775 081	60 184	937 530	5 637 046
Total 2009	39 785 896	4 488 750	1 252 031	4 623 677	50 150 354

APPENDIX II

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E52-24 Old Main Building
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09 December 2013

HREC REF: 667/2013

Prof J Myers
Public Health & Family Medicine
Falmouth Building

Dear Prof Myers

PROJECT TITLE: ESTIMATING THE BURDEN OF INJURY AND VIOLENCE IN SOUTH AFRICA AND IDENTIFYING URBAN-RURAL DIFFERENCES

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study. We acknowledge that the student Ms Megan Prinsloo is also involved as a PhD student on this project.

Approval is granted for one year until the 30th December 2014

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period. (Forms can be found on our website: www.health.uct.ac.za/research/humanethics/forms)

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the HREC reference no in all your correspondence.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN ETHICS
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.
The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

APPENDIX III

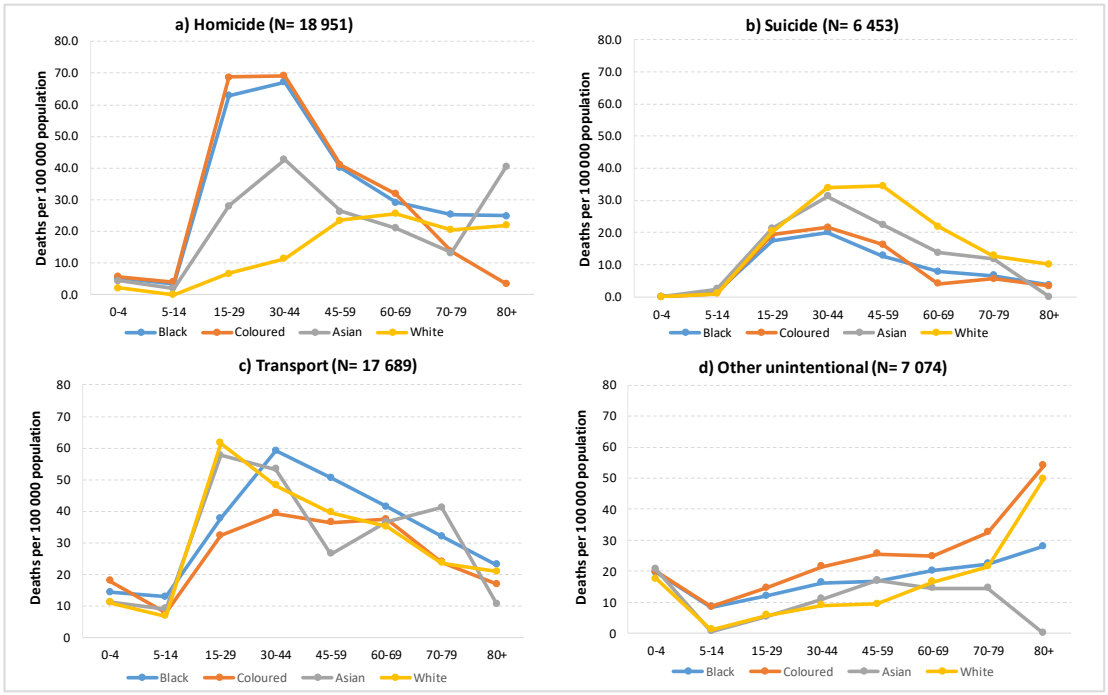

Figure II. Age-specific mortality rates by race for a) homicide, b) suicide, c) transport and d) other unintentional injuries, South Africa 2009

The log likelihood in Figure III shows that for Models 1-5 there were no real differences, regardless of the interaction terms added. However, when fitting the race*age interaction in Model 6, the impact of the increased log likelihood between Model 5 to Model 6 can be observed in Figure III and is closer to zero, indicating a better fit. A marginal increase was observed for Model 7, which was selected as the best model, as it contained a metro/non-metro interaction with race.

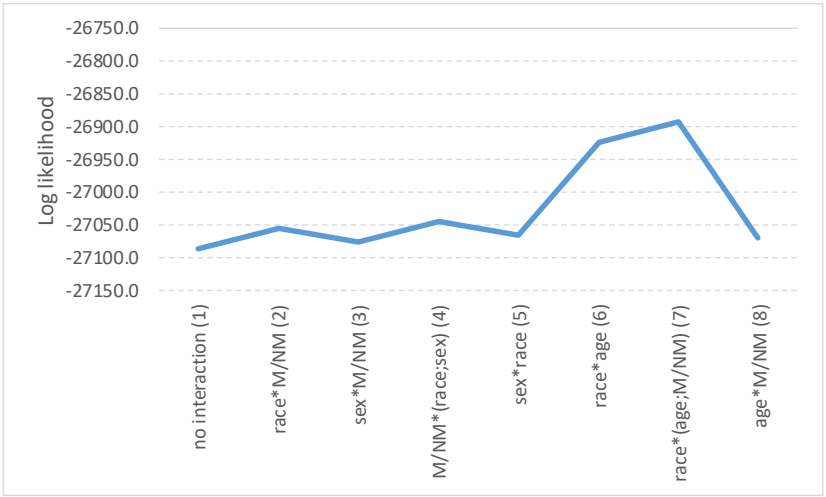

Figure III: Log likelihood for multinomial logistic regression models 1-8

Table IV. Model 1 with no interactions (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
Metro/Non-metro												
Non-metro (ref)	1.00				1.00				1.00			
Metro	1.31	0.003	1.10	1.56	0.97	0.652	0.85	1.11	0.84	0.028	0.72	0.98
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.64	<0.001	1.51	1.77	1.32	<0.001	1.15	1.51	0.99	0.887	0.92	1.07
Race												
White (ref)	1.00				1.00				1.00			
Coloured	1.62	<0.001	1.30	2.01	0.29	<0.001	0.24	0.34	0.38	<0.001	0.31	0.46
Asian	1.56	0.010	1.12	2.17	0.73	0.111	0.50	1.08	0.96	0.726	0.74	1.24
Black	2.00	<0.001	1.73	2.31	0.34	<0.001	0.28	0.41	0.61	<0.001	0.54	0.70
Age group												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.15	<0.001	0.12	0.18	0.09	<0.001	0.07	0.11	0.39	<0.001	0.35	0.43
15-29	2.12	<0.001	1.92	2.34	1.70	<0.001	1.48	1.95	1.25	<0.001	1.13	1.37
30-44	1.62	<0.001	1.51	1.74	1.49	<0.001	1.35	1.65	1.31	<0.001	1.22	1.41
60+	0.59	<0.001	0.52	0.66	0.37	<0.001	0.30	0.45	0.51	<0.001	0.46	0.57
_cons	0.72	0.002	0.60	0.88	2.01	<0.001	1.59	2.54	4.76	<0.001	3.93	5.77

RRR: Relative Risk Ratio *p-value: <0.05 denotes statistical significance ** L CI: Lower Confidence Interval, U CI: Upper Confidence Interval

Table V. Model 2 with race*metro/non-metro interaction (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.63	<0.001	1.51	1.77	1.32	<0.001	1.15	1.51	0.99	0.844	0.92	1.07
Race												
White (ref)	1.00				1.00				1.00			
Coloured	1.33	0.110	0.94	1.89	0.23	<0.001	0.19	0.27	0.23	<0.001	0.18	0.29
Asian	3.54	<0.001	1.89	6.64	1.06	0.869	0.50	2.25	1.62	0.090	0.92	2.84
Black	1.87	<0.001	1.49	2.35	0.37	<0.001	0.30	0.44	0.48	<0.001	0.40	0.57
Age												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.15	<0.001	0.12	0.18	0.09	<0.001	0.07	0.11	0.39	<0.001	0.35	0.43
15-29	2.12	<0.001	1.92	2.34	1.70	<0.001	1.48	1.96	1.25	<0.001	1.13	1.37
30-44	1.62	<0.001	1.51	1.74	1.50	<0.001	1.36	1.66	1.31	<0.001	1.22	1.41
60+	0.59	<0.001	0.52	0.66	0.36	<0.001	0.30	0.45	0.51	<0.001	0.46	0.57
Metro/ Non-metro												
Non-metro (NM) (ref)	1.00				1.00				1.00			
Metro (M)	1.15	0.376	0.84	1.59	1.01	0.960	0.77	1.31	0.52	<0.001	0.41	0.67
Race*M/NM												
White*NM (ref)	1.00				1.00				1.00			
Coloured*M	1.52	0.147	0.86	2.68	1.66	0.007	1.16	2.37	2.75	<0.001	1.90	3.99
Asian*M	0.36	0.008	0.18	0.76	0.63	0.304	0.26	1.54	0.59	0.108	0.31	1.13
Black*M	1.12	0.503	0.80	1.57	0.85	0.323	0.62	1.17	1.60	0.001	1.24	2.08
_cons	0.78	0.037	0.61	0.98	1.98	<0.001	1.62	2.42	6.11	<0.001	5.05	7.39

RRR: Relative Risk Ratio *p-value: <0.05 denotes statistical significance ** L CI: Lower Confidence Interval, U CI: Upper Confidence Interval

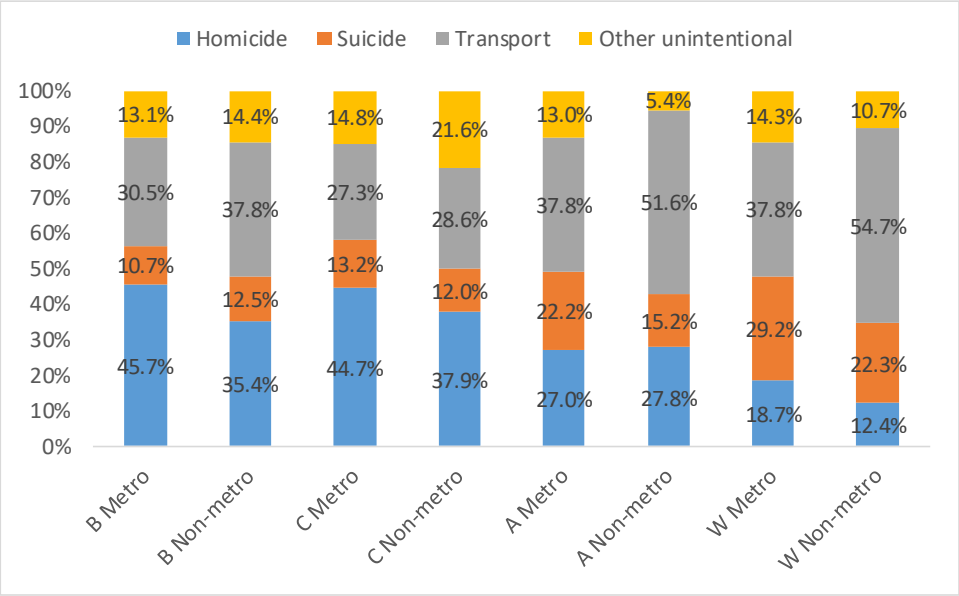

Figure IV. Model 2 Predicted proportions with race*metro/non-metro interaction

Table VI. Model 3 with sex*metro/non-metro interaction (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
Race												
White (ref)	1.00											
Coloured	1.62	<0.001	1.30	2.01	0.29	<0.001	0.24	0.34	0.38	<0.001	0.31	0.46
Asian	1.56	0.009	1.12	2.18	0.73	0.116	0.50	1.08	0.96	0.756	0.74	1.24
Black	1.99	<0.001	1.72	2.30	0.34	<0.001	0.28	0.41	0.61	<0.001	0.53	0.70
Age group												
45-59 (ref)	1.00											
0-14	0.15	<0.001	0.12	0.18	0.09	<0.001	0.07	0.11	0.39	<0.001	0.35	0.43
15-29	2.11	<0.001	1.92	2.33	1.70	<0.001	1.48	1.95	1.24	<0.001	1.13	1.37
30-44	1.61	<0.001	1.50	1.73	1.49	<0.001	1.35	1.65	1.30	<0.001	1.21	1.40
60+	0.59	<0.001	0.52	0.66	0.37	<0.001	0.30	0.45	0.51	<0.001	0.46	0.57
Sex												
Female (ref)	1.00											
Male	1.36	<0.001	1.21	1.52	1.26	0.045	1.01	1.57	0.85	<0.001	0.79	0.92
Metro/Non-metro												
Non-metro (ref)	1.00											
Metro	0.94	0.581	0.76	1.16	0.91	0.390	0.72	1.14	0.64	<0.001	0.52	0.80
sex*M/NM												
Female*NM	1.00											
Male*M	1.53	<0.001	1.30	1.80	1.12	0.375	0.87	1.45	1.43	<0.001	1.24	1.66
_cons	0.84	0.070	0.70	1.01	2.08	<0.001	1.59	2.71	5.35	<0.001	4.40	6.51

RRR: Relative Risk Ratio *p-value: <0.05 denotes statistical significance **L CI: Lower Confidence Interval, U CI: Upper Confidence Interval

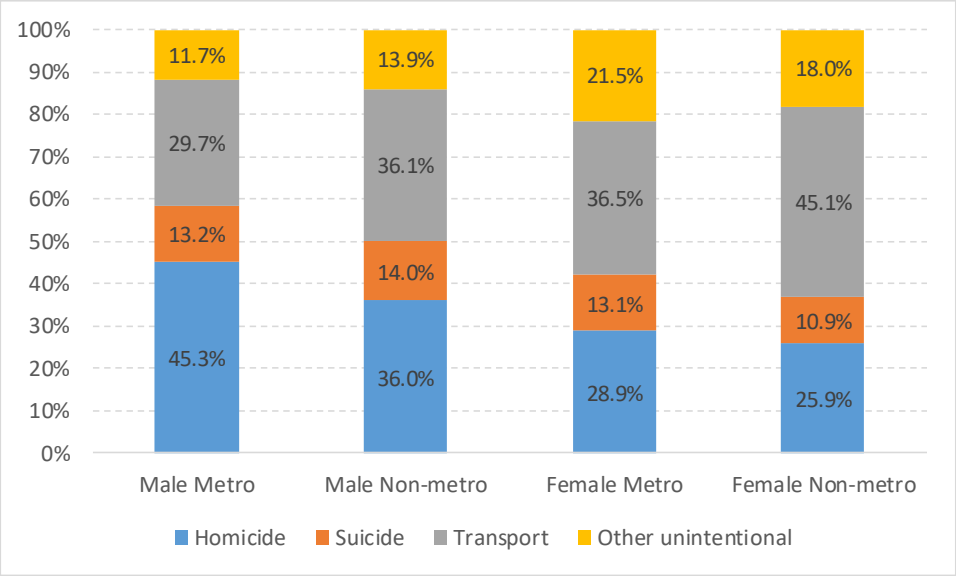

Figure V. Model 3 Predicted proportions with sex*metro/non-metro interaction

Table VII. Model 4 with race*M/NM and sex*M/NM interaction (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
Age group												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.15	<0.001	0.12	0.18	0.09	<0.001	0.07	0.11	0.39	<0.001	0.35	0.43
15-29	2.11	<0.001	1.92	2.33	1.70	<0.001	1.48	1.95	1.24	<0.001	1.13	1.37
30-44	1.61	<0.001	1.51	1.73	1.50	<0.001	1.36	1.65	1.31	<0.001	1.22	1.41
60+	0.59	<0.001	0.52	0.66	0.36	<0.001	0.30	0.44	0.51	<0.001	0.46	0.57
Race												
White (ref)	1.00				1.00				1.00			
Coloured	1.33	0.107	0.94	1.89	0.23	<0.001	0.19	0.27	0.23	<0.001	0.18	0.29
Asian	3.62	<0.001	1.94	6.78	1.08	0.838	0.51	2.28	1.66	0.076	0.95	2.91
Black	1.88	<0.001	1.50	2.36	0.37	<0.001	0.30	0.44	0.48	<0.001	0.40	0.58
M/NM												
Non-metro (ref)	1.00				1.00				1.00			
Metro	0.84	0.359	0.57	1.23	0.92	0.624	0.65	1.30	0.40	<0.001	0.30	0.54
race* M/NM												
W Non-metro (ref)	1.00				1.00				1.00			
C Metro	1.52	0.148	0.86	2.69	1.66	0.007	1.16	2.38	2.75	<0.001	1.90	3.99
A Metro	0.35	0.006	0.17	0.73	0.62	0.290	0.25	1.52	0.57	0.087	0.30	1.09
B Metro	1.10	0.561	0.79	1.54	0.85	0.312	0.62	1.17	1.58	0.001	1.22	2.04
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.35	<0.001	1.21	1.51	1.24	0.057	0.99	1.54	0.85	<0.001	0.79	0.92

sex* M/NM												
Female*NM(ref)	1.00				1.00				1.00			
Male*M	1.54	<0.001	1.31	1.81	1.16	0.253	0.90	1.49	1.44	<0.001	1.25	1.67
_cons	0.90	0.381	0.71	1.14	2.07	<0.001	1.61	2.64	6.84	<0.001	5.64	8.30

RRR: Relative Risk Ratio *p-value: <0.05 denotes statistical significance **L CI: Lower Confidence Interval, U CI: Upper Confidence Interval

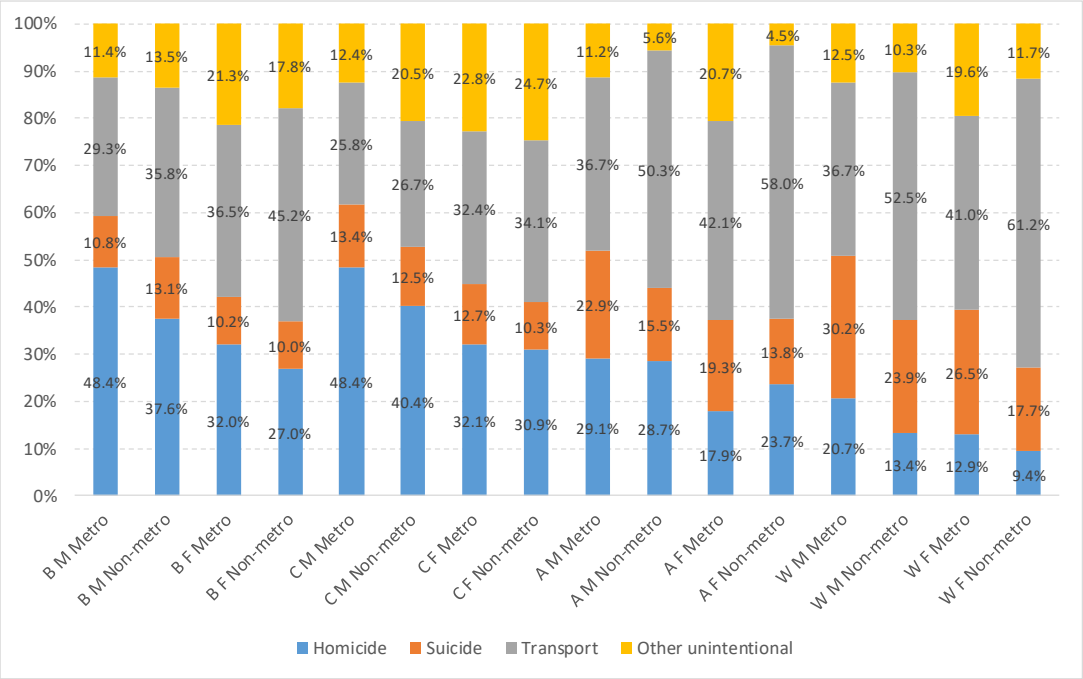

Figure VI. Model 4 Predicted proportions with race*M/NM and sex*M/NM interaction

Table VIII. Model 5 with sex*race interaction (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
M/NM												
Non-metro (ref)	1.00				1.00				1.00			
Metro	1.31	0.003	1.10	1.56	0.97	0.647	0.85	1.10	0.84	0.029	0.72	0.98
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.66	<0.001	1.29	2.14	1.77	<0.001	1.43	2.18	1.49	0.002	1.17	1.89
Race												
White (ref)	1.00				1.00				1.00			
Coloured	1.72	0.001	1.28	2.33	0.40	<0.001	0.31	0.53	0.42	<0.001	0.33	0.53
Asian	1.97	0.065	0.96	4.04	1.42	0.353	0.67	2.99	1.35	0.177	0.87	2.10
Black	1.94	<0.001	1.54	2.45	0.41	<0.001	0.32	0.53	0.86	0.101	0.71	1.03
sex*race												
F*White (ref)	1.00				1.00				1.00			
M*Coloured	0.89	0.416	0.68	1.18	0.63	0.002	0.47	0.83	0.86	0.283	0.65	1.14
M*Asian	0.72	0.267	0.40	1.30	0.42	0.003	0.24	0.73	0.61	0.021	0.40	0.92
M*Black	0.99	0.940	0.79	1.25	0.76	0.041	0.58	0.99	0.62	<0.001	0.49	0.79
Age group												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.15	<0.001	0.12	0.18	0.09	<0.001	0.07	0.11	0.39	<0.001	0.35	0.43
15-29	2.12	<0.001	1.92	2.34	1.70	<0.001	1.48	1.95	1.25	<0.001	1.13	1.37
30-44	1.62	<0.001	1.51	1.74	1.49	<0.001	1.35	1.65	1.31	<0.001	1.22	1.41
60+	0.59	<0.001	0.52	0.66	0.37	<0.001	0.30	0.45	0.51	<0.001	0.46	0.57
_cons	0.74	0.021	0.57	0.95	1.65	<0.001	1.28	2.13	3.61	<0.001	2.81	4.64

RRR: Relative Risk Ratio *p-value: <0.05 denotes statistical significance **L CI: Lower Confidence Interval, U CI: Upper Confidence Interval

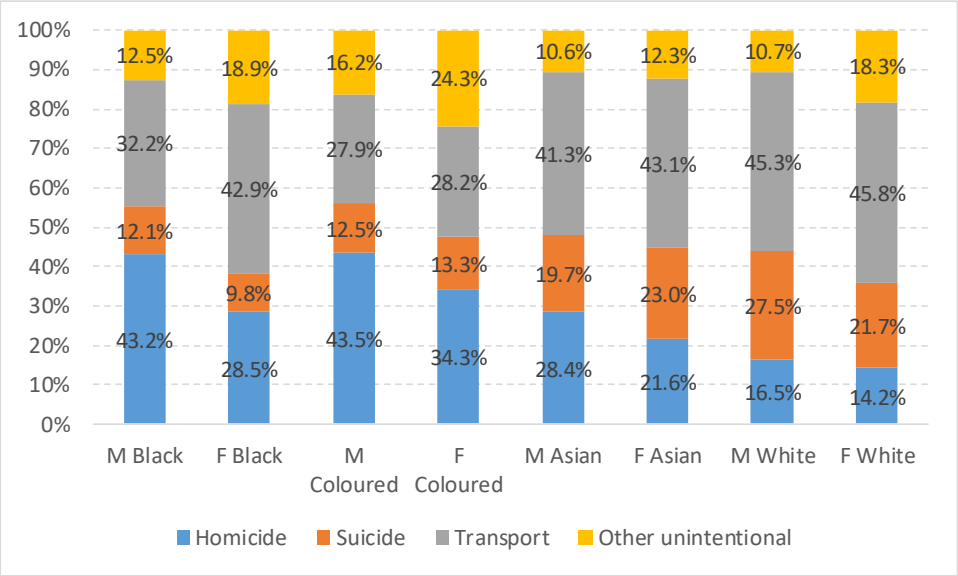

Figure VII. Model 5 Predicted proportions with sex*race interaction

Table IX. Model 6 with race*age interaction (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
M/NM												
Non-metro (ref)	1.00				1.00				1.00			
Metro	1.31	0.003	1.10	1.56	0.98	0.709	0.86	1.11	0.85	0.035	0.72	0.99
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.64	<0.001	1.52	1.78	1.33	<0.001	1.16	1.52	1.00	0.953	0.92	1.08
Race												
White (ref)	1.00				1.00				1.00			
Coloured	0.62	0.014	0.42	0.90	0.17	<0.001	0.11	0.25	0.33	<0.001	0.25	0.44
Asian	0.53	0.075	0.26	1.07	0.34	0.014	0.15	0.80	0.37	0.001	0.22	0.64
Black	0.92	0.597	0.66	1.27	0.20	<0.001	0.15	0.28	0.68	0.011	0.50	0.91
Age group												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.04	<0.001	0.02	0.09	0.03	<0.001	0.01	0.06	0.30	<0.001	0.16	0.53
15-29	0.45	0.001	0.29	0.69	0.95	0.737	0.68	1.31	2.56	<0.001	1.84	3.56
30-44	0.48	0.006	0.29	0.81	1.02	0.917	0.71	1.46	1.29	0.113	0.94	1.77
60+	0.42	<0.001	0.28	0.62	0.21	<0.001	0.16	0.28	0.31	<0.001	0.24	0.40
race*age												
W*45-59 (ref)	1.00				1.00				1.00			
C*0-14	5.74	<0.001	2.68	12.29	2.80	0.022	1.17	6.69	2.12	0.027	1.09	4.10
C*15-29	6.39	<0.001	3.86	10.56	2.19	0.004	1.31	3.66	0.61	0.006	0.43	0.86
C*30-44	4.12	<0.001	2.41	7.05	1.55	0.065	0.97	2.46	0.99	0.958	0.68	1.44
C*60+	1.18	0.429	0.78	1.77	1.12	0.660	0.67	1.87	2.45	<0.001	1.79	3.36
A*0-14	6.71	<0.001	2.47	18.25	6.07	<0.001	2.68	13.75	2.79	0.003	1.45	5.40

A*15-29	7.95	<0.001	2.93	21.57	3.25	0.042	1.05	10.11	2.71	0.036	1.07	6.87
A*30-44	5.29	<0.001	2.42	11.54	2.13	0.028	1.09	4.16	2.40	0.001	1.47	3.92
A*60+	2.55	0.140	0.73	8.97	3.44	0.029	1.14	10.37	5.55	<0.001	3.23	9.54
B*0-14	3.31	0.002	1.56	7.00	3.38	0.003	1.56	7.31	1.18	0.586	0.64	2.17
B*15-29	4.86	<0.001	3.16	7.47	2.01	<0.001	1.51	2.69	0.41	<0.001	0.30	0.57
B*30-44	3.49	<0.001	2.01	6.05	1.58	0.022	1.07	2.34	0.95	0.785	0.67	1.36
B*60+	1.39	0.142	0.89	2.17	2.05	<0.001	1.43	2.95	1.74	<0.001	1.35	2.25
_cons	1.53	0.013	1.10	2.13	3.10	<0.001	2.28	4.21	4.67	<0.001	3.46	6.31

RRR: Relative Risk Ratio [*]p-value: <0.05 denotes statistical significance [**] L CI: Lower Confidence Interval, U CI: Upper Confidence Interval
IRRR[#] : Interactions Relative Risk Ratio for interactions of Race*age -calculated as RRR(race)*RRR(age)*RRR(Race*age)

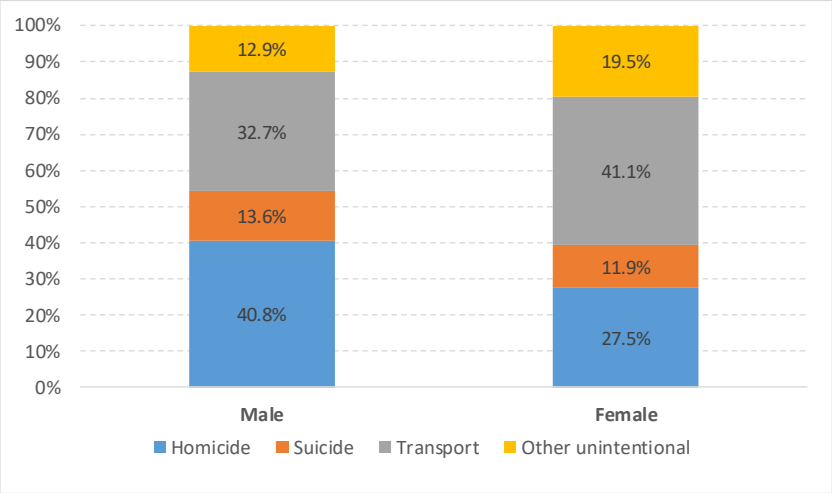

Figure VIII. Predicted proportions of Model 6 (adjusting for age, sex and race) by sex and manner of death

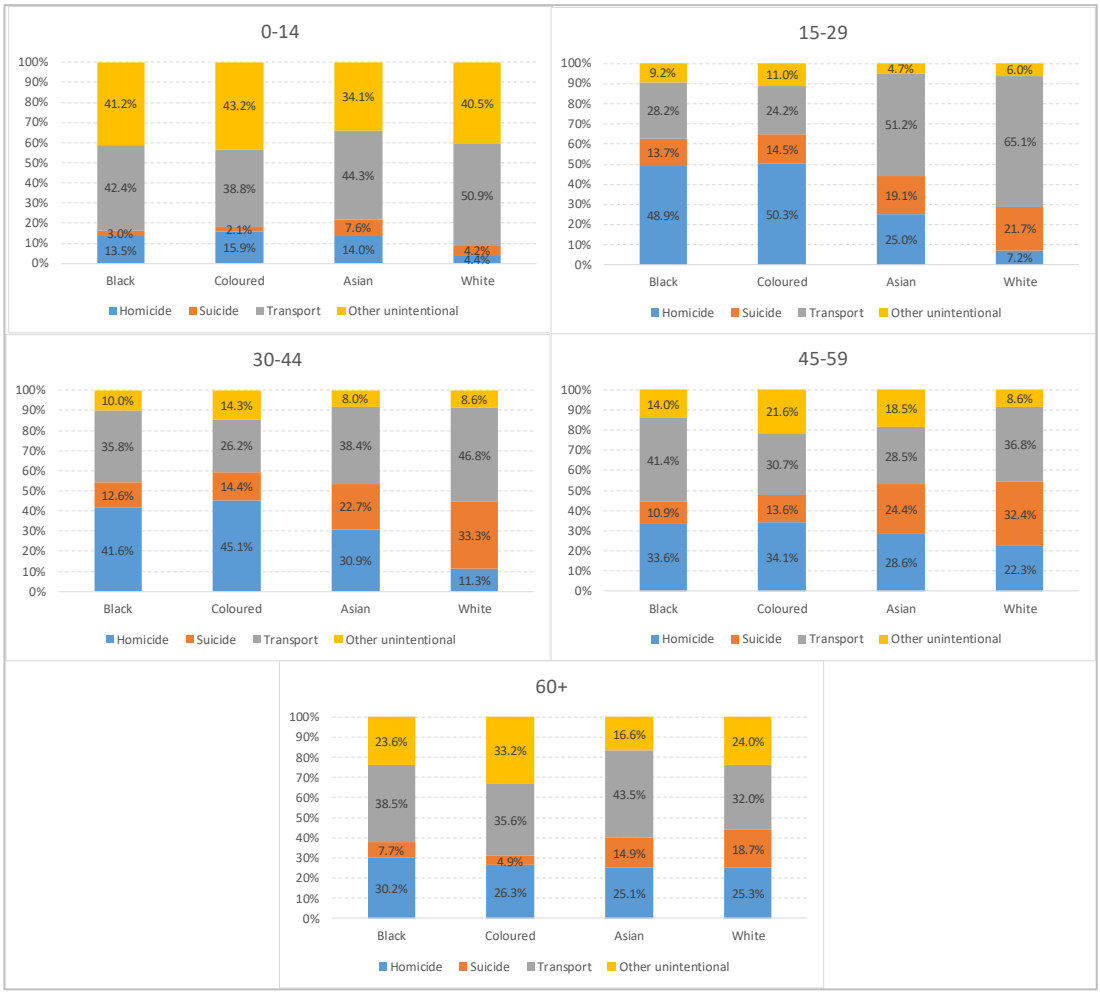

Figure IX. Predicted proportions of Model 6 (adjusting for age, sex and race), by race, age and manner of death

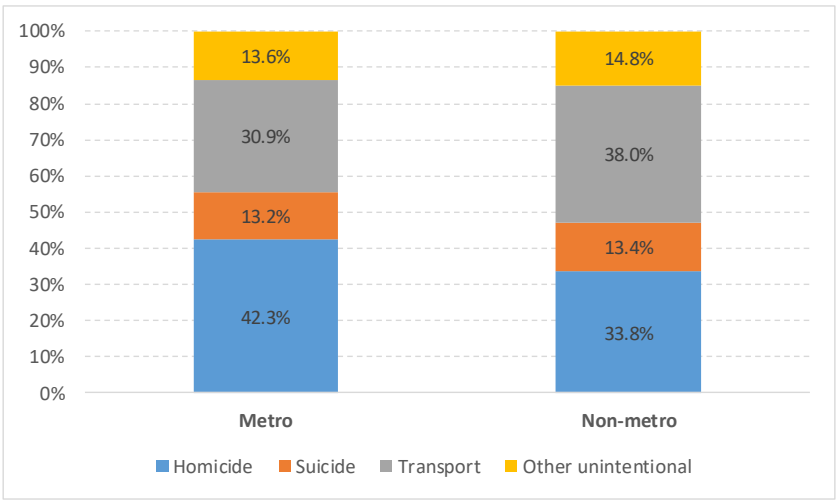

Figure X. Predicted proportions of Model 6 (adjusting for age, sex and race) by metro-/non-metro area and manner of death

Table X. Model 7 with race*age and race*M/NM interaction (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.64	<0.001	1.52	1.77	1.33	<0.001	1.16	1.52	1.00	0.921	0.92	1.08
Race												
White (ref)	1.00				1.00				1.00			
Coloured	0.51	0.005	0.32	0.81	0.13	<0.001	0.08	0.20	0.20	<0.001	0.15	0.28
Asian	1.32	0.501	0.58	3.03	0.51	0.174	0.20	1.36	0.66	0.221	0.34	1.29
Black	0.88	0.473	0.60	1.27	0.21	<0.001	0.15	0.30	0.54	<0.001	0.39	0.73
Age group												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.04	<0.001	0.02	0.09	0.03	<0.001	0.01	0.06	0.31	<0.001	0.17	0.56
15-29	0.44	0.001	0.28	0.70	0.94	0.733	0.68	1.32	2.67	<0.001	1.91	3.73
30-44	0.49	0.007	0.29	0.82	1.02	0.928	0.71	1.45	1.36	0.060	0.99	1.87
60+	0.42	<0.001	0.29	0.62	0.21	<0.001	0.16	0.28	0.33	<0.001	0.25	0.42
race*age												
W 45-59 (ref)	1.00				1.00				1.00			
C 0-14	5.79	<0.001	2.70	12.40	2.90	0.016	1.23	6.84	2.10	0.026	1.10	4.01
C 15-29	6.42	<0.001	3.85	10.68	2.19	0.003	1.31	3.65	0.58	0.003	0.41	0.83
C 30-44	4.15	<0.001	2.42	7.12	1.58	0.048	1.01	2.48	0.96	0.819	0.67	1.38
C 60+	1.11	0.587	0.75	1.66	1.04	0.875	0.61	1.78	2.20	<0.001	1.56	3.09
A 0-14	5.45	0.003	1.81	16.39	5.77	<0.001	2.39	13.97	2.31	0.016	1.18	4.52
A 15-29	7.42	<0.001	2.76	19.93	3.18	0.044	1.03	9.80	2.47	0.055	0.98	6.23
A 30-44	5.20	<0.001	2.37	11.40	2.14	0.025	1.10	4.14	2.29	0.001	1.41	3.70
A 60+	2.77	0.111	0.79	9.76	3.57	0.026	1.17	10.91	5.82	<0.001	3.43	9.88
B 0-14	3.30	0.002	1.55	7.02	3.38	0.003	1.56	7.32	1.13	0.687	0.61	2.09

B15-29	4.87	<0.001	3.14	7.54	2.02	<0.001	1.52	2.69	0.39	<0.001	0.28	0.55
B 30-44	3.47	<0.001	1.99	6.05	1.60	0.018	1.09	2.35	0.91	0.586	0.63	1.30
B 60+	1.38	0.146	0.89	2.12	2.04	<0.001	1.42	2.92	1.67	<0.001	1.29	2.17
M/NM												
Non-metro (ref)	1.00				1.00				1.00			
Metro	1.18	0.302	0.86	1.61	0.99	0.926	0.76	1.28	0.51	<0.001	0.40	0.64
race*M/NM												
W Non-metro (ref)	1.00				1.00				1.00			
C Metro	1.52	0.139	0.87	2.67	1.72	0.004	1.20	2.48	2.84	<0.001	1.95	4.13
A Metro	0.34	0.004	0.16	0.70	0.61	0.284	0.25	1.52	0.61	0.130	0.32	1.16
B Metro	1.10	0.572	0.79	1.52	0.87	0.385	0.64	1.19	1.66	<0.001	1.28	2.16
_cons	1.61	0.009	1.13	2.30	3.08	<0.001	2.29	4.13	5.91	<0.001	4.42	7.90

RRR: Relative Risk Ratio *p-value: <0.05 denotes statistical significance **L CI: Lower Confidence Interval, U CI: Upper Confidence Interval

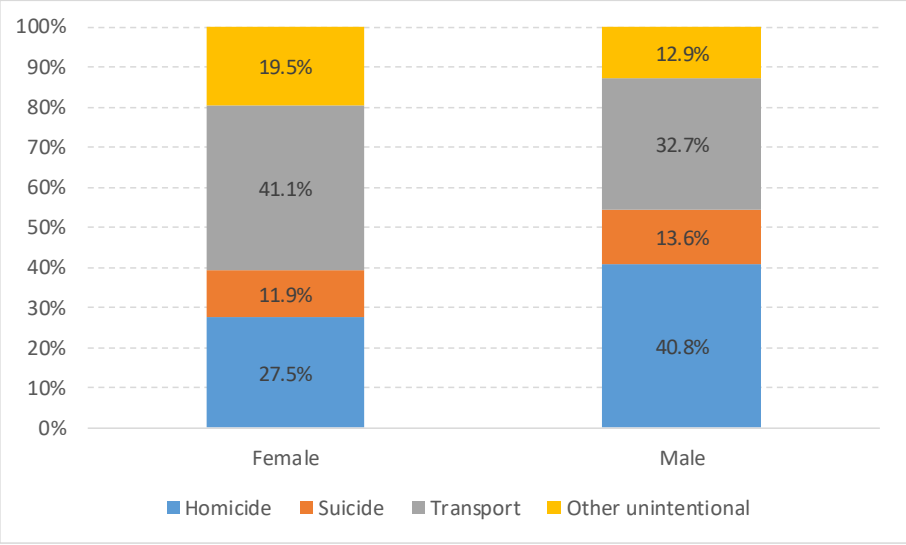

Figure XI. Predicted proportions of Model 7 (adjusting for age, sex and race) by sex and manner of death

Figure XII. Predicted proportions of Model 7 (adjusting for age, sex and race), by race, age and manner of death

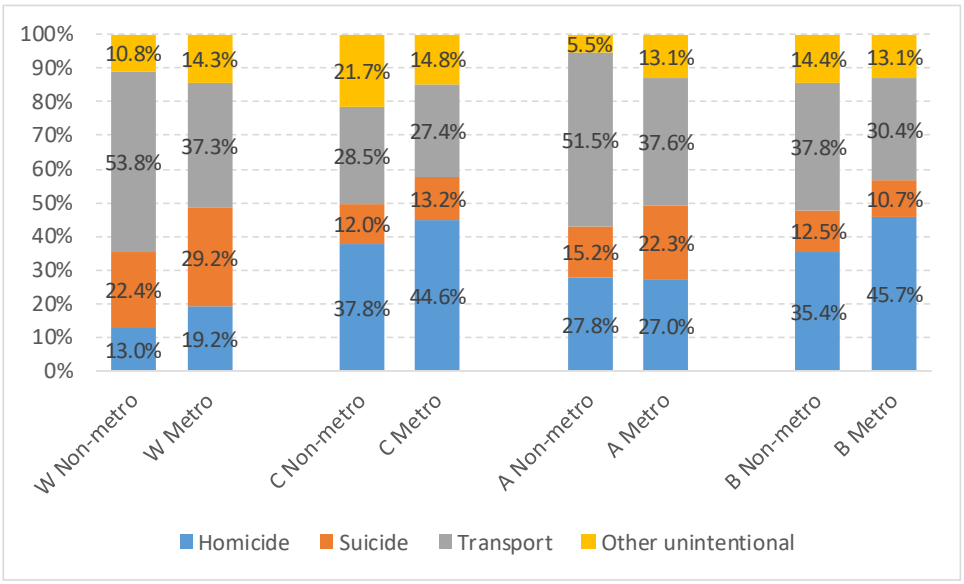

Figure XIII. Predicted proportions of Model 7, adjusting for age, sex and race by metro-/non-metro area, manner of death and race

Table XI. Model 8 with age group*M/NM interaction (Other unintentional as reference outcome)

	Homicide				Suicide				Transport			
	RRR	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****	**RRR**	**p-value***	**L CI****	**U CI****
Sex												
Female (ref)	1.00				1.00				1.00			
Male	1.63	<0.001	1.51	1.77	1.32	<0.001	1.15	1.51	0.99	0.887	0.92	1.07
Race												
White (ref)	1.00				1.00				1.00			
Coloured	1.60	<0.001	1.29	1.98	0.28	<0.001	0.24	0.34	0.38	<0.001	0.31	0.45
Asian	1.53	0.013	1.10	2.14	0.72	0.099	0.49	1.07	0.95	0.684	0.73	1.23
Black	1.96	<0.001	1.70	2.25	0.34	<0.001	0.28	0.41	0.61	<0.001	0.53	0.70
Age group												
45-59 (ref)	1.00				1.00				1.00			
0-14	0.20	<0.001	0.16	0.25	0.11	<0.001	0.07	0.16	0.42	<0.001	0.37	0.49
15-29	2.20	<0.001	2.00	2.43	1.87	<0.001	1.63	2.14	1.32	<0.001	1.16	1.50
30-44	1.64	<0.001	1.50	1.79	1.60	<0.001	1.41	1.82	1.37	<0.001	1.25	1.50
60+	0.77	0.001	0.66	0.89	0.52	<0.001	0.39	0.70	0.59	<0.001	0.50	0.68
M/NM												
Non-metro (ref)	1.00				1.00				1.00			
Metro	1.54	<0.001	1.28	1.86	1.26	0.068	0.98	1.62	0.99	0.893	0.83	1.17
Age group* M/NM												
45-59*NM (ref)	1.00				1.00				1.00			
0-14*M	0.50	<0.001	0.37	0.67	0.57	0.029	0.34	0.94	0.82	0.080	0.66	1.02
15-29*M	0.91	0.411	0.73	1.14	0.81	0.139	0.60	1.08	0.87	0.116	0.74	1.04
30-44*M	0.95	0.523	0.81	1.11	0.84	0.071	0.70	1.02	0.90	0.120	0.78	1.03

60+*M	0.54	<0.001	0.42	0.70	0.45	<0.001	0.31	0.66	0.74	0.005	0.60	0.91
_cons	0.69	<0.001	0.58	0.82	1.83	<0.001	1.48	2.26	4.49	<0.001	3.70	5.45

RRR: Relative Risk Ratio *p-value: <0.05 denotes statistical significance **L CI: Lower Confidence Interval U CI: Upper Confidence Interval

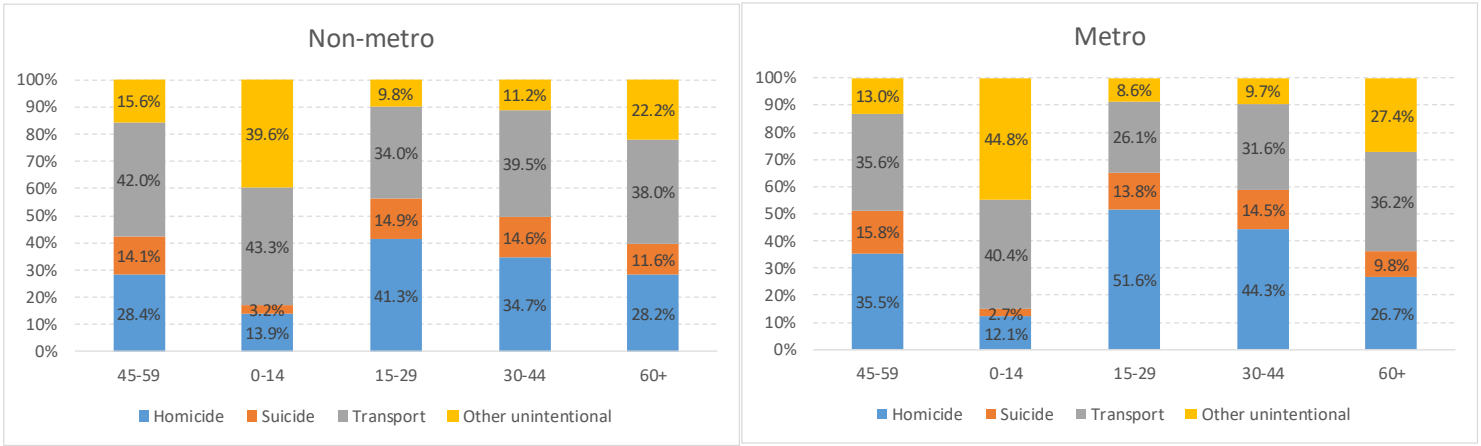

Figure XIV. Predicted proportions of Model 8, adjusting for age, sex and race by metro-/non-metro area, manner of death and age

Table XII. Provincial distribution of homicide by metro/non-metro area, South Africa 2009

	Homicide					
	Metro		Non-metro		Total	
Province	*N*	%	*N*	%	*N*	%
Eastern Cape	1 185	(12.0)	2 272	(24.7)	3 458	(18.2)
Free State	0	(0.0)	970	(10.6)	970	(5.1)
Gauteng	4 436	(45.1)	0	(0.0)	4 436	(23.3)
KwaZulu-Natal	2 579	(26.2)	2 200	(23.9)	4 779	(25.1)
Limpopo	0	(0.0)	860	(9.4)	860	(4.5)
Mpumalanga	0	(0.0)	668	(7.3)	668	(3.5)
North West	0	(0.0)	829	(9.0)	829	(4.4)
Northern Cape	0	(0.0)	607	(6.6)	607	(3.2)
Western Cape	1 646	(16.7)	776	(8.5)	2 422	(12.7)
Total	9 846	(100.0)	9 182	(100.0)	19 028	(100.0)