THE BODY COUNT:

USING ROUTINE MORTALITY SURVEILLANCE DATA TO DRIVE VIOLENCE PREVENTION

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I dedicate this thesis to the late David Bourne, whose infectious enthusiasm for routine data and their wide range applications was a constant source of inspiration and motivation for this work.

CONTENTS

DECLARATION

This thesis is presented in fulfillment of the requirements of the degree of Doctor of Philosophy (PhD) in the Department of Public Health & Family Medicine, Faculty of Health Sciences, July 2012. The work on which this thesis is based is original research and has not, in whole or in part, been submitted towards another degree, at this university or elsewhere. The university is empowered to reproduce either the whole or any portion of the contents for the purposes of research.

ACKNOWLEDGEMENTS

The nature of public health research and resource intensive projects such as injury surveillance typically involves many partner organisations and individuals. This implies intensely collaborative work and I am grateful to numerous colleagues that have guided and shaped the surveillance system and the data it has generated. My involvement arose from the pioneering work of Dr Len Lerer, a forensic pathologist based at the University of Cape Town and attached to the state mortuary in Salt River, who first recognised the potential of data from the post-mortem investigative process to inform injury prevention in South Africa. Len supervised my research project in the final year of my business science degree and oversaw the publication of the first city-level report for Cape Town in 1994. I am particularly indebted to Len for mentoring me and first sparking my interest in public health. Several other colleagues were central to this work. Dr Rozett Phillips of the Medical Research Council's (MRC) Health Consulting Office collected and collated the data for the first city-level report and co-wrote the second report for 1995. David Bourne kindled Len and my interest in railway injuries and fatalities and also linkages with all cause surveillance along with Dr Debbie Bradshaw of the MRC. Debbie beneficiated the data for use in her burden of disease work, and who would later become a most reliable and supportive manager as Director of the MRC's Burden of Disease Research Unit during the completion of my thesis.

Our work in Cape Town also prompted Dr Alex Butchart at UNISA to replicate our project as a national pilot in collaboration with Dr Margie Peden (MRC National Trauma Research Programme) and Dr Niresh Bhagwandin (MRC Technology and Business Development Group), who managed the overarching project funded by the Department of Arts Culture, Science and Technology. It was this project that provided the foundation for the multi-city project upon which this thesis is based and I am grateful to numerous colleagues for the dedication and support that ensured this project's success. Stephanie Burrows, who assisted Alex at UNISA in Johannesburg, and Ashley van Niekerk have also utilised the surveillance data for PhD purposes and were co-authors of several of the first annual reports of the National Injury Mortality Surveillance System (NIMSS). Prof. Brett Bowman (University of the Witwatersrand) has been a frequent collaborator and co-author of NIMSS-related outputs.

The integrity of the data was reliant on the dedication and commitment of the researchers and technologists that served as regional co-ordinators once the surveillance system was established across several major South African cities. In particular, I am grateful to Hilton Donson who co-ordinated many of the Eastern and Northern Cape sites, Anesh Sukhai in KwaZulu Natal and Christine Harris in Gauteng and Mpumalanga. Megan Prinsloo, along with Hilton, oversaw the integration of the various data sets as well as linkages with the blood alcohol data from the chemical laboratories, and also co-ordinated the Western Cape data collection activities. I am particularly grateful to her for overseeing the collation and publication of the 2005 NIMSS data following my secondment to UCT. It is very pleasing that although several of the aforementioned colleagues have chosen to further their careers at other institutions, some of them overseas, many of us are still in regular contact and still collaborate on related projects.

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Ms Christelle Kotzenberg in the National Health Department for championing this initiative when necessary. In the Western Cape, the visionary work of the Burden of Disease Reduction Project led by Prof Craig Househam, Dr Krish Vallabjhee and Dr Tracey Naledi, has prompted the expansion of the system in the province, but certainly credit is also due to Ms Vonita Thompson, Head of the provincial Forensic Pathology Service and her team for their willingness and flexibility to ensure its institutionalisation.

Of course, there are many other pathologists, mortuary personnel and departmental staff that warrant some form of acknowledgement, and not yet mentioned, but fundamental to the existence of the surveillance system are the numerous users of the data and its outputs. I am averse to attempt a comprehensive listing in case of an inadvertent omission, but detailed acknowledgements of the many, many individuals and agencies that have contributed to aspects of the surveillance system have been acknowledged in annual reports and other outputs over the years. I say again, thank you to all that have been instrumental in progressing this important work.

Finally, a deep debt of gratitude is owed to my supervisors, Prof Jonny Myers and Prof Mary Lou Thompson for their insightful comment and critical advice. Jonny has patiently helped to guide, shape and contain my thesis and also navigate some issues regarding the research protocol, its final format and complex data ownership issues. Mary Lou has seamlessly guided and encouraged my immersion into the more complex statistical analysis that has given this work much of its richness. Both have been exceptionally reliable and timeous in providing the guidance and support and attention to detail that I have required despite the numerous disruptions caused by travel and competing priorities that can so easily bedevil the part-time candidate.

I hope that this thesis can, in some way, enrich and enhance the work of the many individuals that have supported its evolvement and, above all, that it will inform activities that will make our society safer.

OVERVIEW

The thesis is divided into six broad chapters: 1 - Introduction, 2 - Literature review, 3 - Reflections on the utility of the surveillance system and the quality of the data generated, 4 – Aims and objectives, 5 - Methods, 6 - Results, 7 – Discussion, and 8 – Conclusions and recommendations for future surveillance and research.

Chapter 1 provides background to the thesis and sets out the need for injury surveillance in the South African context, and describes the advent and development of a mortuary-based surveillance system.

Chapter 2, the literature review, describes the extent of violence and injury in South Africa with a particular focus on homicide and road traffic injuries as well as providing an overview of the evidence for risk factors and prevention strategies for these two important injury sub-groups. The literature review will also describe the evaluation criteria with which effective surveillance systems are routinely assessed, as well as the findings of preliminary evaluations.

Chapter 3 – assesses the utility of the surveillance system and the quality of the data generated by revisiting and updating an earlier assessment of the pilot surveillance system.

Chapter 4 sets out the aims and objectives of the thesis, which draw on the information presented in the introduction, literature review and surveillance system assessment.

Chapter 5 describes the methodological issues relating to the surveillance system and the study described in this thesis under the following headings: study design, data sources, representativeness, case report form and key variables, data capture and cleaning, data quality, data management, data analysis, estimation, and ethics.

Chapter 6 provides an exploratory analysis of the data describing their completeness in comparison to police data. It shows the distribution of the various explanatory variables prior to a multivariable analysis of the hypotheses set out in Chapter 4.

The discussion in Chapter 7 provides an overview of homicide in the five cities and then assesses the utility of the findings from Chapter 6, namely: the role of key explanatory variables as predictors of homicide and the effect of the Firearms Control Act on firearm homicide. The discussion also identifies some of the limitations of the study and the surveillance system as well as identifying opportunities for further development.

Chapter 8 provides conclusions and recommendations for future surveillance activities and research.

CHAPTERS AND SUBHEADINGS

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ABSTRACT

This thesis describes the conceptualisation, development and implementation of a mortuary-based system for the routine collection of information about homicide. It traces the evolution of the system from its conceptualisation in 1994, through various iterations as a city-level research tool, to a national sentinel system pilot, as a multi-city all-injury surveillance system, and finally its institutionalisation as a provincial injury mortality surveillance system in the Western Cape. In so doing, it demonstrates that the data arising from medico-legal post-mortem investigations described in this thesis were an important source of descriptive epidemiological information on homicide. The 37,037 homicide records described in the thesis were drawn from Cape Town, Durban, Johannesburg, Port Elizabeth and Pretoria, for which the surveillance system maintained full coverage from 2001 to 2005. The aim was to apply more complex statistical analysis and modelling than had been applied previously.

The literature review described the pattern of interpersonal violence in South Africa, the risk factors and interventions for interpersonal violence according to an ecological model, as well as evaluation frameworks for assessing the utility of injury surveillance data. Several established risk factors for interpersonal violence were routinely available from the surveillance data and these informed the specific *a priori* hypotheses regarding the relationship between homicide and the various covariates. These can be summarised according to three broad objectives, i.e. that:

1. *age*, *sex*, *race*[1], *day of week*, *city* and *year of death* were expected to constitute independent predictors of homicide;
2. effect measure modification was hypothesised involving the relationships between *city*, *race*, *sex* and *age*;
3. there would be a significant decrease in firearm homicide coinciding with the period preceding the introduction of gun control legislation in 2004 during which time there was stricter licensing and reduced gun circulation.

[1] *Race* was used as a proxy variable for socio-economic status in this thesis. White, Asian, Coloured and African, the apartheid-era racial classifications were used to denote decreasing levels of economic status due to the differential and enduring effect of apartheid-era legislation.

Exploratory analysis of the data described the relationship between homicide counts and the other covariates and included graphical representations of the data. Multivariable analysis ascertained the role of different covariates in explaining variability in homicide rates. A generalised linear model was constructed that included the following covariates: *age*, *sex*, *race*, *city*, *year of death* and *day of week* and *population* as the exposure variable. The assumption was that the mortality counts were Poisson distributed, i.e. with the characteristic that mean=variance=μ, i.e.:

$\ln(\mu)$ = linear combination of coefficients for *age*, *sex*, *race*, *city*, *year of death*, *day of week* (with interactions) = $X\beta$

The results confirmed that key risk factors for violence identified in the literature review were also independent predictors of homicide in five major cities, and, most importantly, that the commonly understood association between socio-economic status and violence was equally valid in South Africa. It provided a basis for understanding common misperceptions of homicide risk comparing cities, or the gender or "race" of victims. For example, the analysis dispelled previous findings by other researchers based on more simplistic and inappropriate analysis suggesting that Coloured people bore a disproportionate burden of violence. It also showed that race modified the effect of the age-homicide relationship, with the wealthier groups experiencing a significantly higher homicide risk with increasing age.

The confirmation that the risk pattern for violence and aggressive behavior hold true in South Africa lends credence to the adoption of violence prevention approaches that have proven successful in other settings. The thesis confirmed that one such strategy, i.e. stricter firearm control, was responsible for the significant overall decrease in homicide during the study period. The results also revealed discrepancies between homicide estimates based on the mortuary data and official police statistics. This suggested not only the need for the ongoing collection and analysis of reliable and routine data such as can be provided by mortuary-based surveillance systems, but also independent and capacitated scientific oversight to interrogate data, draw meaningful and accurate inferences, understand the limitations of the data and affect ongoing improvements, such as through the expansion of non-fatal injury surveillance.

GLOSSARY

AIC - Akaike Information Criterion

autopsy - examination of a cadaver (dead body) to determine or confirm the cause of death

BIC - Bayesian Information Criterion

CI – confidence interval

CSIR – Council for Scientific and Industrial Research

DoH – Department of Health

external cause of injury - the agent or energy that gives rise to the injury. Common external causes for violence related injuries include firearms, sharp force (e.g. stabbing), blunt force (e.g. assault and battery).

FCA – Firearms Control Act

FPS – Forensic Pathology Service

GLM – generalised linear model

homicide – the unlawful and intentional killing of a person by another person

injuries – damage to a person caused by an acute transfer of energy (mechanical/kinetic, thermal, chemical, electrical, radiation) or by a sudden absence of heat (hypothermia) or oxygen (asphyxiation, drowning)[2]

IRR - incidence rate ratios

ISHS - Institute for Social Health Sciences

LMICs – low- to middle-income countries

MRC – Medical Research Council

murder - the unlawful and intentional killing of another human being[3]

NIMSS – National Injury Mortality Surveillance System

nosology – the systematic classification of diseases

PHRC - Provincial Health Research Committee

PIMSS – Provincial Injury Mortality Surveillance System

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[2] Berger, L. R., & Mohan, D. (1996). *Injury control: A global view*. New Delhi: Oxford University Press.

[3] Republic of South Africa. Criminal Procedure Act (Act 51 of 1977).

post-mortem - examination of a cadaver (dead body) to determine or confirm the cause of death, i.e. autopsy.

SAPS - South African Police Service

SE – standard error

SES – socio-economic status

suicide – the killing of oneself

UNISA – University of South Africa

violence - The intentional use of physical force or power, threatened or actual, against oneself, another person, or against a group or community, that either results in or has a high likelihood of resulting in injury, death, psychological harm, maldevelopment or deprivation[4]

WHO – World Health Organisation

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[4] WHO Global Consultation on Violence and Health 1996, *Violence: a public health priority*, World Health Organization, Geneva. (document WHO/EHA/SPI.POA.2).

CHAPTER 1: INTRODUCTION

1.1. Background

Sub-Saharan Africa is one of only two regions in the world where gains in life expectancy are being reversed, the other being former states of the Soviet Union (Caselli, Meslé et al. 2002, McMichael, McKee et al. 2004) and the disease and death profile predominantly reflects the protracted polarised model proposed by (Frenk, Bobadilla et al. 1989) in that infectious diseases affect the poor, chronic diseases related to an urbanised lifestyle affect both the rich and poor, and there is a large burden of morbidity and mortality from non-natural causes, i.e. trauma and violence, particularly amongst the poor. Bradshaw, Schneider, Dorrington, Bourne and Laubscher (2002) observed that in South Africa the poor suffer disproportionately from all three patterns of mortality simultaneously along with a fourth burden arising from HIV/AIDS and related conditions.

Injuries are an important public health issue in South Africa, where a disproportionate amount of the burden of disease from non-natural causes in South Africa is due to violence and road traffic injuries (Norman, Matzopoulos et al. 2007). According to data submitted to the WHO, the country is amongst the most violent in the world (Altbeker 2005) and has even been described as having a "culture of violence" (Vogelman, Lewis 1993). Similarly, the mortality rate due to road traffic injuries is nearly double the global average (Norman, Matzopoulos et al. 2007). Yet amidst daily press reports highlighting gruesome acts of violence and official reports that crime and in particular violent crime are among the most pressing challenges facing South Africa, there are several indications that the rate of fatal violence may have peaked and is beginning to decrease (Bah 2004, Louw 2006). Furthermore, the high rates of violent injuries are not well understood; much less the risk factors for other types of injuries, such as road traffic injuries, burns, drowning and self inflicted injuries. One of the reasons is that reliable injury surveillance data, the cornerstone of prevention efforts in many other countries, have not been available until the advent of the injury mortality surveillance system described in this thesis.

The analysis of mortality trends is a useful starting point to gaining a better understanding of the risk factors that predispose individuals to the risk of injury-related death. Yet in contrast to other major causes of morbidity and death in South Africa, i.e. HIV/AIDS and other infectious and chronic diseases, where trends have been well documented few studies in the scientific literature describe trends in non-natural mortality in South Africa post 1990. MacDonald and Lerer(1994) describe trends in firearm and non-firearm homicide and suicide and Flisher et al. (1994, 2004) describe South African suicide trends, but the data are drawn from much earlier sampling periods (1986 to 1991 and 1968 to 1990 respectively). The only papers describing more recent homicide trends in the medical literature, i.e. between 1993 and 2004, are restricted to the Transkei region of the Eastern Cape Province (Meel 2004, Meel 2005). Based on an analysis of post-mortem records, Meel (2004) found that the murder rate in the Transkei had increased significantly between 1993 and 1999 from 94 to 121 per 100,000 population. In particular, there was a dramatic increase in firearm homicides from 27 to 42 per 100,000 between 1993 and 2004 (Meel, 2005).

Although they may be true for the Eastern Cape, the findings seem to contradict Bah's (2004) analysis of mortality among men and women aged 15 – 49 years from the Department of Home Affairs population register, which suggested that at a national level deaths due to non-natural causes have been decreasing between 1993 and 2000; the turning point having occurred in 1996 for males and in 1997 for females. Bah's findings are supported by the recent report of Statistics South Africa, which also showed a steady decrease in the number and proportion (of all mortality) of non-natural from 1997 to 2001. More recent data for 2006 show that there is a slight increase in the overall number of non-natural deaths, but that these represent a smaller percentage of total deaths (Table I). The report suggests that there was an increase in death certification coverage of more than 10percent between 2001 and 2006, suggesting that the 2006 data are in fact reflecting a further decline in non-natural deaths.

In their synopsis of the value and limitations of commonly-used sources of injury data, Berger and Mohan(1996) surmise that while official registries of death are often the most accurate source of information on serious injuries, they are compromised when the persons completing death reporting lack extensive training. The poor quality of cause of death certification in South Africa, and of injury deaths in particular, was highlighted in an editorial in the *South African Medical Journal* (Groenewald, Pieterse 2007). With regard to the non-natural cause mortality reported by Bah (2004), it was not possible to determine whether the decrease reflected a decrease in homicide, as the intent was described as "undetermined" for three-quarters of injury deaths; i.e. it was not clear whether the deaths were due to homicide, suicide or unintentional (accidental). This uncertainty also extended to the cause of death for deaths due to undetermined intent, in that 67percent were due to "unspecified" causes; i.e. it was not clear whether the deaths were due to poisoning, hanging, drowning, firearm discharge or other causes (Statistics South Africa 2005).

Table I. Natural and non-natural deaths[1]: 1997, 1999, 2001 and 2006

Cause of death	1997		1999		2001		2006	
	No.	%	No.	%	No.	%	No.	%
Natural	264,285	83.0	328,671	86.1	401,812	88.9	554,570	91.3
Non-natural	54,002	17.0	53,231	13.9	50,124	11.1	52,614	8.7
Total	**318,287**	**100.0**	**381,902**	**100.0**	**451,936**	**100.0**	**607,184**	**100.0**

Source: Statistics South Africa (2005) for 1997 to 2001 data; Statistics South Africa (2009) for 2006 data.

Another important indicator of homicide trends is the "murder rate" reported in the annual crime statistics of the South African Police Services, which is frequently used as an indicator for the rate of fatal violence in the absence of reliable and detailed vital registration data. Official crime statistics by the South African Police Service (SAPS) indicate consistent year-on-year decrease in the murder rate; from 26,832 to 15,940

[1] The non-natural category includes homicide, RTI's, unspecified injury deaths and everything else injury related. It is not clear which sub-category is causing the decrease.

murders per 100,000 population between 1994/95 and 2011/12 (Table II), reflecting an overall decrease of more than 40 percent over the last 12 years (South African Police Services 2011, Criminal Justice Monitor no date).

Table II. SAPS murder statistics from 1994 to 2010

Year	Total murders
1994/95[1]	25,965
1995/96[1]	26,877
1996/97[1]	25,470
1997/98[1]	24,486
1998/99[1]	25,127
1999/00[1]	22,604
2000/01[1]	21,758
2001/02[1]	21,405
2002/03[1]	21,553
2003/04[2]	19,824
2004/05[2]	18,793
2005/06[2]	18,528
2006/07[2]	19,202
2007/08[2]	18,487
2008/09[2]	18,148
2009/10[2]	16,834
2010/11[2]	15,940

1. South African Police Services 2011; 2. Criminal Justice Monitor no date

However, these data too have their limitations. Firstly, as crime statistics are based on murder dockets that are reported to and captured by the Crime Incident Analysis Centre rather than on a "body-count" through vital registration, they are vulnerable to under-reporting. There is also pressure on police to under-report, as their performance is evaluated on the basis of crime statistics. In a national study of female homicide in 1999, Mathews et al. (2004) found that police dockets were missing or could not be traced for more than 13percent of murders. Secondly, the police statistics reveal no details about murder victims or the circumstances of their deaths.

As regards other causes of injury deaths, the national transport information system records information for an incomplete subgroup of motor vehicle collision deaths (it excludes railway deaths). Deaths due to suicide and other unintentional causes (e.g. fires, falls, poisoning), and where the manner of death is undetermined, are not tracked by any agencies. In summary, it is difficult to establish whether there has indeed been a substantial decrease in injury related mortality, and it is also difficult to surmise reasons for any true trend, without accurate, reliable and timely information on injury events and presumptive or known risk-factors. A dedicated injury surveillance system can, among other things, verify the decreasing trend and provide additional detail about the underlying causes.

1.2. The case for injury surveillance

"Surveillance" as used in the field of public health is defined as "the ongoing, systematic collection, analysis, interpretation and dissemination of health information" (Holder, Peden et al. 2001). As described by Butchart et al.(2001), injury surveillance is a fundamental component of the broader public health approach to violence and injury prevention, which recognizes clear patterns in the relationship between various injury types and high-risk groups, times, places and circumstances. It is an important mechanism for defining injury problems and priorities, identifying risk factors, and designing, implementing, and eventually evaluating, interventions.

Declich and Carter describe good quality mortality data as being fundamental for informing health resource allocation decisions (Declich, Carter 1994). The timely dissemination of these data to various stakeholders is an important aspect, as it leads to the application of the data to prevention and control initiatives, and hence an effective surveillance system includes the capacity for dissemination via public health programmes (Holder et al., 2001). In cities where programmes to reduce the burden of injury-related mortality and morbidity have been implemented successfully, unified surveillance systems for fatal injuries have been important precursors (Acero 2004, Guerrero 2006).

In high-income countries such as the USA, Australia and Canada, governmental organisations play a leading role in the organisation and management of these systems. For example, publication of the US *Morbidity and Mortality Weekly Report* (MMWR) devolved to the Centers for Disease Control (CDC) from the National Office of Vital

Statistics in 1962. Ideally, injury surveillance systems are designed, implemented, organised and managed by research or academic institutions in collaboration with governmental and non-governmental organisations. In Canada, the Network for Health Surveillance is a partnership involving people interested in health surveillance from all levels of government, non-governmental organisations and universities. The Network defines health surveillance as the tracking and forecasting of any health event or health determinant through the collection of data and its integration, analysis and interpretation into surveillance products, and the dissemination of those surveillance products to those who need to know. In the pursuit of more effective health surveillance practices the Network is building the standards and system tools needed so that public health decision-makers in Canada can access the information via the Internet to better meet public health needs. Similarly, in Australia, the National Injury Surveillance Unit (NISU) is the collaborating unit of the Australian Institute of Health and Welfare (AIHW) in the area of injury. NISU is a separate, identifiable activity of the Research Centre for Injury Studies at Flinders University, and the AIHW provides the core funds which allow NISU to operate. The Commonwealth Department of Health and Ageing provides additional funds, enabling NISU to undertake projects for that agency.

However, most low to middle-income countries do not have sophisticated injury surveillance systems in place and initial support is often received from external agencies. For example, WHO is working with the Ministries of Health in several African countries to strengthen the surveillance capacity of the national health systems. In Jamaica the Ministry of Health's Division of Health Promotion and Protection in collaboration with the CDC and other research and academic institutions established the Violence-related Injury Surveillance System. The system was first designed and implemented at Kingston Public Hospital to develop strategies to reduce the impact of violence-related injuries on Jamaican health care resources. Upon successful implementation, the system was expanded by the Ministry of Health to support needed policy changes to minimise the impact of injuries on the health services and on the health of the population (Ward, Durant et al. 2002).

To address the dearth of fatal and non-fatal injury data emanating from Africa, the World Health Organisation with its research partners has supported injury surveillance activities in several African countries, including Mozambique and Ethiopia (Bartolomeos, Peden 2003). At the same time, doctors and injury prevention practitioners in Uganda have pioneered a reliable trauma registry system that includes information geared towards prevention as well as recording clinical conditions (Kobusingye, Lett 2000). Yet despite these pilot studies, no other country in Africa has an injury mortality surveillance system as extensive as South Africa's. The availability of such a large data set therefore presents a unique opportunity to explore variations in the distribution of fatal injuries and changes in relevant risk factors over time.

1.3. The advent of a mortuary-based surveillance system in South Africa

In South Africa, public health oriented research groups started epidemiological investigations into the causes and consequences of violence and injuries as a basis for improved injury prevention and control in the late 1980s (Butchart, Brown 1991, Lerer 1992, van der Spuy 1993, Nell, Brown 1991). Mortuary-based data arising from medico-legal post-mortem investigations were an important source of descriptive epidemiological information as the investigations typically collated information from three points in the investigative procedure: 1) the post-mortem reports that are completed by forensic pathologists, 2) the crime incident reports of the South African Police Services and 3) chemical pathology laboratory results.

South Africa's strict medico-legal code requires that all non-natural deaths be examined by a district surgeon, forensic pathologist or medical practitioner under the Inquests Act of 1959 (Republic of South Africa 1959), which suggested that more detailed information was available and that full coverage of non-natural deaths was possible, particularly in urban centres. Similar information was not readily available from other sources such as through vital registration. The Births and Deaths Registration Act of 1992 only required recording whether a death was due to “natural causes” or, in the case of a death due to other than natural causes, “unnatural causes” or “under investigation" (Republic of South

Africa 1992), Therefore the data arising from the post-mortem investigation process constituted a rich and important source of information with which to describe fatal violence and injury patterns, identify risk factors and groups at risk, to inform prevention efforts and to monitor their effectiveness.

An all-injury mortality surveillance system was piloted in Cape Town in the mid-1990s following on from a UCT honours research project in which 1993 data were extracted retrospectively from the death registers and documentation at the two mortuaries at Salt River and Tygerberg (Matzopoulos 1994). The Cape Town Non-natural Mortality Study Group comprising researchers at UCT and the MRC compiled two technical reports describing injury mortality in the Cape Metropole in 1994 and 1995 (Cape Town Non-natural Mortality Study Group, Health Consulting Office 1996, Non-natural Mortality Study Group 1998), as well as a journal article describing the annual data for 1994 (Lerer, Matzopoulos et al. 1997). The studies demonstrated the data's utility in identifying injury control priorities, and concluded with a call for the initiation of similar projects by stakeholders at provincial and national levels.

A related project demonstrated the data's prevention potential in respect of railway injuries that culminated in a technical report (Lerer, Matzopoulos 1995) formulating a public-health-oriented prevention approach as well as several journal articles. The first article described the circumstances of injury, groups at-risk, and the level of underreporting of injuries by the rail utility, and in so doing demonstrated the importance of mortuary-based data in complementing a comprehensive, sustainable railway injury surveillance system to promote safety engineering and law enforcement (Lerer, Matzopoulos 1996). A second described the features of railway-related deaths (Lerer, Matzopoulos 1997) and the third juxtaposed historical mortality data against current data in order to address recurrent themes of limited safety enforcement by the rail operator, victim blaming and public concern (Matzopoulos, Lerer 1998). More recently, a case-control study, undertaken as the candidate's MPhil (Epidemiology) research project, investigated the relationship between alcohol and rail-related passenger and pedestrian fatalities during daylight hours as compared to road traffic injury passenger and pedestrian fatalities as respective controls. The study concluded that alcohol played a similar role in increasing risk amongst both rail passengers and pedestrians (Matzopoulos, Peden et al. 2006).

In 1998, the mortuary-based system that had been demonstrated in Cape Town was replicated in a national pilot in an attempt to improve methods for the monitoring and prevention of injuries in South Africa through a national sentinel surveillance system, i.e. the National Injury Mortality Surveillance System, or NIMSS (Butchart, Peden et al. 2001). The NIMSS formed part of the "Violence and Injury Surveillance for Violence Prevention", a consortium comprising the Medical Research Council (MRC), Council for Scientific and Industrial Research (CSIR) and the University of South Africa (UNISA), which was funded by the Department of Arts, Culture, Science and Technology's Innovation Fund. Other projects included a pilot hospital-based surveillance system (Matzopoulos, Prinsloo et al. 2006) and a trauma, drug and alcohol study (Plüddemann, Parry et al. 2004, Parry, Plüddemann et al. 2005). The mortuary-based surveillance system was the fulcrum around which the other activities were based and it constituted single surviving component following the end of the project's funding cycle at the end of 2000. The Medical Research Council continued to manage the project from its Technology and Business Development Group on an ad hoc basis until October 2001, when it was incorporated into the Crime, Violence and Injury Lead Programme affiliated to the Medical Research Council and the UNISA Institute for Social Health Sciences (ISHS)[2], with the following aims:

- To provide ongoing and systematic information about the incidence, causes and consequences of all non-natural deaths at local, provincial and national levels;
- To enable the early identification of new injury trends and emerging problem areas so that adequate interventions can be timeously established;
- To determine priorities for injury and violence prevention action, both for high-risk groups and socio-environmental risk factors;

[2] These two institutions continue to maintain the NIMSS in Gauteng and Mpumalanga although the name of the collaboration has changed to the Safety and Peace Promotion Lead Programme.

- To help evaluate direct and indirect violence and injury prevention and control measures; and
- To monitor seasonal and longitudinal changes in the non-natural death profile.

During this period, the further expansion of the surveillance system centred on attaining full coverage of major cities (see Table III), which would enable several new developments in terms of analysis and reporting, specifically the estimation of urban mortality rates to enable comparison with one another and the development of city mortality reports. This would become an increasingly important initiative to drive localised prevention, and which coincided with the country's continued rapid rate of urbanisation.

Table III. NIMSS coverage 1999-2005

Year	Total no of				Notes
	Cases	Mortuaries	Cities	Provinces	
1999	14829	10	1	5	Full coverage of Cape Town and Kimberley. Partial coverage of Durban, East London, Johannesburg, Port Elizabeth, Pretoria.
2000	18 876	15	3	5	Full coverage of Port Elizabeth, Pretoria
2001	25 361	32	6	6	Full coverage of Durban, East London, Johannesburg. Partial coverage of Mpumalanga.
2002	25 494	36	6	6	Full coverage of Stellenbosch
2003	24 600	35*	6	7	Full coverage of Klerksdorp, Potchefstroom
2004	23 938	35*	6	7	-
2005	23 541	21*	5	6	Mpumalanga excluded. Mdantsane excluded. Kingwilliamstown/Bisho included.

* The variability in the number of participating mortuaries was the result of erratic compliance in Mpumalanga.

From 2003, expansion was limited and a consolidation and rationalisation phase followed, brought about by the large caseload and the numerous participating facilities, which each required individual reports. Data collection and cleaning manuals were developed and three regional co-ordinators were appointed to conduct training, provide oversight and collate data. Data were centrally warehoused at the Medical Research Council and migrated to a secure Sequel server due to space limitations of the original database software. The development of automated report-writing software was a further innovation, which was first employed for the 2002 Annual Report (Matzopoulos, Seedat et al. 2003) and associated mortuary-specific reports.

With the total number of non-natural deaths in South Africa estimated at 59,935 in 2000 (Norman, Matzopoulos et al. 2007), the NIMSS represented approximately 40percent of non-natural mortality between 2001 and 2005. The extent of coverage was not comparable to systems in high-income countries (HICs), which tended to utilise central registration system. Instead the CDC drew weekly mortality data from 121 cities, which only represented approximately one-third of US injury deaths. Yet despite the inclusion of 14 out of a total of 19 mortuaries in Mpumalanga in 2001 and three from the North West Province in 2003, the NIMSS remained more representative of the urban rather than the rural injury mortality profile. The difficulty in implementing and sustaining the system at numerous poorly resourced rural mortuaries preceded the fundamental shift in the NIMSS to a more explicitly city-oriented focus.

There were several benefits of a city focus for injury prevention research and safety promotion. Cities offered accessible city level management, defined populations and geographical boundaries for effective tracking and evaluation of intervention impacts and outcomes, and more accessible strategy and policy documentation (Matzopoulos, Seedat 2005). In addition, several sources of data were routinely available through streamlined and centralised information systems and, with regard to mortality reporting, there was a lower likelihood of deaths going unreported than in the rural areas.

1.4. Reporting and dissemination of surveillance results to stimulate prevention

Routine annual reports were a feature of both the Cape Town city-wide pilot study and the NIMSS. The two technical reports from the pilot surveillance system in Cape Town in 1994 (Lerer, Matzopoulos et al. 1995) and 1995 (Cape Town Non-natural Mortality Study Group, Health Consulting Office 1996), and the first annual report of the NIMSS (Violence and Injury Surveillance Consortium 2000) as well as the two journal articles describing these studies in the *South African Medical Journal* (Butchart, Peden et al. 2001, Lerer, Matzopoulos et al. 1997) were distributed among policy makers and public health researchers with a specific interest in violence and injury prevention to demonstrate the utility of this routine data source in providing detailed information on the circumstance and manner of non-natural deaths. For example, the first annual report of the NIMSS was disseminated widely among key stakeholders in local, provincial and national government and among South African and international research and prevention agencies. Government departments and agencies included the Departments of Safety and Security, Justice and Constitutional Development, Health, and Transport, and the Greater Johannesburg Metropolitan Council, and Statistics South Africa. Research and prevention agencies included Gun Free South Africa, the Gun Control Alliance, the Industry Association for Responsible Alcohol Use, UNISA, CSIR, MRC, the local chapters of the Child Accident Prevention Foundation and the Global Road Safety Partnership, and international agencies such as the World Health Organisation (Burrows 2001).

Burrows (2001), identified three main stakeholder groups. First, forensic medicolegal services could utilise the NIMSS information for allocating resources, auditing costs and rationalising services, as they did not have a routine system recording how many deaths were being processed through their facilities. Second, the NIMSS would provide crucial baseline data on deaths due to violence and other injuries that could be of use for routine crime prevention initiatives that could utilize data on demographic and geographic profiles of violent deaths in addition to information on the cause of death and related factors, such as the use of firearms and/or alcohol. Third, the NIMSS provides descriptive information for injury prevention agencies and researchers, including those affiliated with the criminal justice system, to design, implement and evaluate preventive interventions.

Customised reports were also produced for some of the agencies in response to properly motivated requests. These included reports prepared for the Department of Safety and

Security's Social Crime Prevention Division, the Department of Justice's Crime Control Division, the Department of Health's Directorate of Mental Health and Substance Abuse and its Gauteng Executive Committee, and Greater Johannesburg's Child Friendly Cities Initiative (Burrows 2001). In addition, several journal articles were compiled describing methodological aspects and preliminary results of the pilot study (Matzopoulos, Bowman et al. 2001, Prinsloo, Matzopoulos et al. 2000).

Annual reports were published for each subsequent year up to and including 2005 (Burrows, Bowman et al. 2001, Matzopoulos 2002, Matzopoulos, Seedat et al. 2003, Matzopoulos 2005, Matzopoulos 2005, Prinsloo 2007) The reports were frequently launched at dedicated seminars, where standard descriptive analyses were presented alongside new and key findings of public health importance. The *Second Annual Report of the National Injury Mortality Surveillance System, 2000* (Burrows, Bowman et al. 2001) was released in 2001 along with a summary report (Matzopoulos, Bowman et al. 2001) to coincide with the launch of the Medical Research Council/UNISA Crime, Violence and Injury Lead Programme at a public seminar at the Medical Research Council's Cape Town campus, and the *Third Annual Report of the National Injury Mortality Surveillance System, 2001* (Matzopoulos, 2002) was released at a symposium hosted by UNISA in Johannesburg. Both reports were widely disseminated among government, and research and prevention agencies. Basic descriptive analysis of data from the annual reports focussing on specific injury subsets formed the basis for further articles and book chapters, e.g. firearm violence (Prinsloo, Matzopoulos et al. 2003), the alcohol-relatedness of injury deaths (Matzopoulos 2005), violence against children (Matzopoulos, Bowman 2006) and road traffic injuries among children (Matzopoulos, Du Toit et al. 2008).

As well as annual national reports, mortuary-specific annual and quarterly reports were produced for each participating mortuary during the pilot phase not only to assist with planning and service delivery, but also as motivation for the various forensic pathology service stakeholders among the police and department of health personnel. However, as the surveillance system expanded and the initial seed funding provided by through the

Innovation Fund was exhausted, the ongoing compilation of technical reports became onerous. Quarterly reports for participating mortuaries were replaced by annual reports due to the large number of mortuaries included in the system (i.e. in the major cities as well as numerous mortuaries in small towns) and eventually an automated report-writing software programme was developed during the course of 2001 and 2002.

The automated report-writing system was first utilised in the compilation of the fourth NIMSS Annual Report for 2002 (Matzopoulos, Seedat et al. 2003) along with mortuary-specific annual reports for each participating mortuary. These mortuaries also received facility-specific cleaned and finalised annual data sets for further analysis. For 2003, the fifth NIMSS Annual report was again compiled manually in order to provide comprehensive detail on city-specific priorities for four major cities, namely Cape Town, Durban, Johannesburg and Pretoria (Matzopoulos 2005). This report included more detailed analysis that was not available in the more succinct automated report and was in line with the project's city-level injury prevention focus. For 2004, the automated report-writing software was adapted to provide city-specific chapters along with the national report (Matzopoulos 2005), a format that was retained for the 2005 report (Prinsloo 2007). In addition, age-standardised mortality rates for the major causes of injury mortality, which had been calculated using Excel spreadsheets (Microsoft Corporation 2002), were included within each chapter.

Another response by the MRC-UNISA researchers to the overwhelming demand for data by outside agencies, was to establish a review process for data requests. A simple data request form was devised and a review committee established comprising an in-house team of MRC–based researchers. The aim was to share the additional workload equitably among the project team, to avoid duplication of effort, to ensure the legitimacy of data requests and to manage data usage and to keep track of copies and versions of the electronic data. Unit records (i.e. the raw data) were only provided with all identifying information removed, and only if there had been a favourable review of a full study protocol by the review committee as well as a health research ethics committee. Most requests however took the form of customised reports, which were compiled in-house by MRC researchers

Despite the numerous outputs that have appeared in annual reports and similar occasional publications prior to this thesis, the analysis of the surveillance data to date has seldom extended beyond simple descriptive statistics. This thesis therefore sets out to consolidate the analysis of the surveillance system into a larger body of work that critically examines the utility of using routine mortuary-based surveillance data for driving injury prevention.

The analysis will include data collected between 2001 and 2006, which coincides with the period that the NIMSS was under this doctoral thesis candidate's management. During this time the candidate managed the collection, cleaning and analysis of data. The candidate edited four annual reports (in 2001, 2002, 2003 and 2004), oversaw the development of the automatic report-generating software, and managed the collection of the 2005 data, which culminated in the 2005 report. The 2005 annual report was released in 2007 and was edited by the subsequent NIMSS manager, a mentee of the candidate. The NIMSS annual reports were widely cited in local and international media during the period under the candidate's management and were utilised extensively by a range of prevention agencies spanning the governmental, non-governmental and private sectors.

However, subsequent to the departure of the candidate and his mentee to other research units the NIMSS coverage has become more erratic. No annual report was released for 2006, but the 33,513 deaths included in the 2007 annual report represented 56percent of estimated injury deaths nationally, the most extensive coverage achieved to date. This was the final year in which data collection was under the management of the candidate's mentee. The 2008 NIMSS annual report omitted to include city-specific chapters, as full coverage was not maintained in Durban and Pretoria. Thereafter, the Western Cape mortuaries were excluded from the NIMSS, as agreement could not be reached between MRC/UNISA and the Western Cape Health Department regarding data ownership. NIMSS data collection activities have since focused on two provinces: Mpumalanga, where full coverage was achieved in 2009 and Gauteng, where all-but-one mortuary provided data for 2009. No national annual report has been released since 2008.

This thesis aims to apply more complex modelling than has previously been applied in various NIMSS outputs. As the surveillance data have already been utilized for two PhD theses focusing on suicide (Burrows) and burns (Van Niekerk) respectively, this thesis will focus exclusively on the analysis of homicide. The literature review in Chapter 2 further informed the aims and objectives of this thesis, and these are made explicit in Chapter 3. The thesis then explores the effect of various presumptive explanatory variables on the incidence of homicide for the period 2001 to 2005 and critically examines the utility of the surveillance data.

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CHAPTER 2: LITERATURE REVIEW

Injury mortality rates in South Africa are considerably higher than in other regions of the world. The most important contributors are interpersonal violence and road traffic injuries, which together accounted for more than 70 percent of injury deaths nationally in 2000. Homicide rates were estimated at five and eight times higher than the global average for females and males respectively, whereas road traffic injury fatality rates were approximately double global averages (Norman, Matzopoulos et al. 2007). In their chapter on injuries in the *South African Health Review*, Butchart and Peden (1997) surmised that South Africa's injury problems were not likely to abate of their own accord, as technological development and urbanisation were usually accompanied by increasing per capita injury rates (Butchart, Peden 1997, Mercy, Butchart et al. 2002). Hence the analysis of injury patterns and risk factors in urban areas constitutes an important starting point for effective prevention.

This literature review encompassed thematic database searches of South Africa and international violence and injury literature from 1990 using the EBSCO platform hosted by UCT Libraries. Additional texts were gleaned from the references lists of articles, the website and technical reports of the World Health Organization and the candidate's own archives. It provides an overview of the extent and distribution of violence in South Africa and its causes and consequences drawn from various data sources and the academic literature with a focus on fatal violence, i.e. homicide (section 2.1). Risk and protective factors (section 2.2) and interventions (section 2.3) are examined using an ecological model. Section 2.4 describes methods for evaluating surveillance systems.

2.1. Overview of the extent and distribution of violence in South Africa

The WHO's *World report on violence and health* delineates violence according to three broad categories: (1) self-directed violence, including self-abuse and suicidal behaviour, (2) collective violence, including warfare, political violence, terrorism and other means to advance specific social agendas, and (3) interpersonal violence, which includes family and intimate partner violence and violence directed at unrelated individuals, but in a proximal community setting (Figure 1) [3]. This typology, which also specifies the nature of violence, whether physical, sexual, psychological or involving deprivation or neglect, provides a useful tool with which to describe the complex patterns of violence and to delineate and develop different prevention strategies (Dahlberg, Krug 2002). It is clear that as routine information on violence outcomes is extremely limited in low income contexts, that it is physical violence that is most easily measureable. In South Africa, the priority category is interpersonal violence, which is the focus of this literature review, and it is fatalities, i.e. homicide, that is the aspect of physical violence that is most readily measured through data such as those described in this thesis.

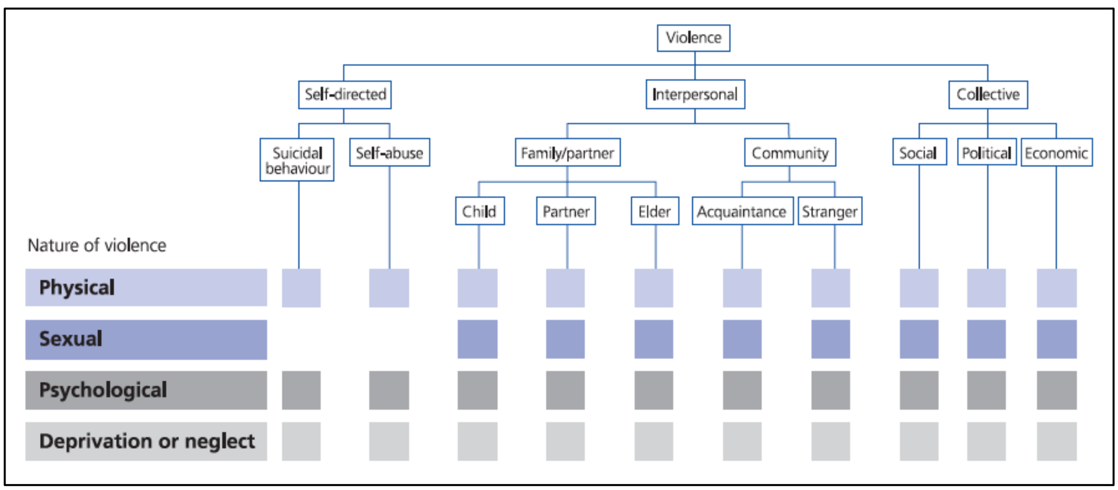

Figure 1. A typology of violence

Source: Dahlberg and Krug, 2002

The homicide rates estimated by Norman et al (2007) placed South Africa among the most violent countries in the world. The chances of dying violently in South Africa were approximately 6.5 times the global average overall and some 30 percent higher than in

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[3] Although this summary divides the typology into six categories that encompass most of the available literature, it is clear that these categories are not mutually exclusive. For example, domestic violence that includes intimate partner violence frequently affects children in the household. In the case of gang and mob violence, these are generally seen as a manifestation of community violence between strangers, although within both there are aspects of collective violence. Collective violence, however, usually refers to violence with more macro societal manifestations, usually as a result of wars or internal armed conflicts.

the WHO's AFRO[4] region (Norman et al 2007) where intentional deaths are more often the result of war and conflict than interpersonal violence (Matzopoulos, Bowman et al. 2008). The overview in this sub-section applies the WHO typology for interpersonal violence to highlight the extent to which interpersonal violence permeates South African society across both family and community settings.

Homicide rates among children in South Africa aged 0 to 14 years were double the global average (Norman et al. 2007). In an address to parliament in September 2005, the Minister of Safety and Security reported statistics on crimes of a serious nature directed at children in the previous year which provide a clear indication of the severity of the situation. There were 1128 children murdered and 1569 cases of attempted murder (6 percent of the total for all ages), 24,189 assaults with the intention to commit grievous bodily harm (10 percent of all reported cases), 31,607 common assaults (12 percent of all cases), 22,486 rapes (41 percent), 4,289 indecent assaults (47 percent)[5]. The child abuse rate and the rate for neglect and ill-treatment were both estimated at 14 per 100,000 population for 2004 (SAPS 2004). A further concern is that as well as being at risk of abuse or being the victims of violence in the home, South African children are frequently exposed to violence to others in the home (Emmet 2003) and young people are also frequently exposed to high levels of community violence.

In the Lavender Hill and Steenberg area in Cape Town, over 70 percent of a sample of primary school children reported had witnessed violence (Van der Merwe, Dawes 2000) and another cross-sectional study revealed that more than 50 percent of all boys and girls had experienced violence, either as victims or perpetrators (Swart, Seedat et al. 2002). One study of Xhosa-speaking youths in a township, half selected from a children's home and half from an informal settlement known for high levels of violence, recorded all of the 60 respondents as having witnessed community violence. 56 percent had been victims and 45 percent had witnessed at least one murder. The psychological impact of these experiences manifested in 22 percent of these children fitting the diagnosis for post

[4] The WHO's African Regional Office (AFRO) represents countries in sub-Saharan Africa.
[5] The parliamentary figures were released on by Minister Nqakulu on 21 September 2005 (Nqakula 2005).

traumatic stress disorder, 32 percent for dysthymia and 7 percent for major depression (Ensink, Robertson et al. 1997).

There is also clear evidence of risk-taking behaviour and a culture of aggression. In their study of high school dropouts in Cape Town high school, dropouts were at increased risk of engaging in risk-taking behaviour (Flisher, Chalton 1995). The Youth Risk Behaviour study conducted by the Medical Research Council in 2002 among a nationally representative sample of learners in public sector schools revealed that approximately 17 percent of learners carried weapons and that approximately 30 percent of learners had been involved in a physical assault in the past six months (Medical Research Council 2002).

Violence is common within the domestic environment as well as in the community and domestic violence has direct effects on children, with one study suggesting that the high proportion of cases in which young children were injured unintentionally may be attributed to their becoming shields in assaults committed by adults (Fieggen, Wiemann et al. 2004). As regards intimate partner violence a study conducted by the MRC, based on a representative sample of female homicide victims, revealed that in 2001 approximately half of all women murdered were killed by an intimate partner. At 8.8 per 100,000 population the national intimate partner homicide rate was the highest recorded in the world (Mathews, Abrahams et al. 2004).

One of the reasons cited for abuse and beatings within relationships is the denial of sex to partners by women (Wood, Jewkes 1997), and sexual violence also features prominently in the South African context. Wood and Jewkes (1997) asserted that South Africa had the highest rates of violence against women in the world, excluding countries at war. There were 210 rape cases reported per 100,000 population in 1990 compared to 80 per 100,000 in the United States (Jewkes, Abrahams 2002). A study of women attending antenatal clinics in Soweto found that 55 percent had been victims of physical or sexual violence (Dunkle, Jewkes et al. 2004) and Swart et al. (2002) found that one-third of women presenting to medico-legal clinics for rape in Johannesburg had been gang-raped. The

1998 Demographic and Health Survey found that 10 percent of 15-19 year old females had had sex against their will and that half of these had been physically forced (Medical Research Council 2003).

The "how, when and where" of homicide in South Africa

In 2003, firearms were the leading external cause of fatal violence across all age groups from the age of five years (Table IV). Gunshot injuries accounted for 53 percent of male and 41 percent of female homicides. The 46 recorded firearm deaths among children aged 0–14 years in Cape Town, Durban, Johannesburg and Pretoria/Tshwane were all violence-related except for one unintentional injury death in Johannesburg. It is estimated that in 2005 there were 3.7 million guns in personal hands in South Africa and that 95 percent of gun owners were men. Not only were firearm fatality rates per 100,000 population among the world's highest, but so too were ownership rates for licensed firearms per 100,000 population: 302 per 100,000 in South Africa versus 4 per 100,000 in the United States (Keegan 2006). More recently, there have been indications that the firearm homicide rate is decreasing. The latest NIMSS report for 2008 showed that sharp force injuries (stabbings) accounted for 40 percent of homicides compared to 29 percent for gunshots (Donson 2009).

Table IV. Leading external causes of violent death by age group, 2003

Rank	Age in years					
	<1	1-4	5-14	15-29	30-49	50+
1	Blunt force 7	Blunt force 14	Firearms 47	Firearms 2273	Firearms 1984	Firearms 370
2	Strangulation 4	Firearms 13	Sharp force 31	Sharp force 1478	Sharp force 1215	Sharp force 202
3	Firearms 3	Sharp force 7	Blunt force 20	Blunt force 477	Blunt force 598	Blunt force 144
4	Sharp force 2	Burns 3	Strangulation 9	Strangulation 49	Strangulation 58	Strangulation 40
5		Strangulation 1	Burns 7	Burns 18	Burns 21	Burns 9

Source: Adapted from Harris et al. (2004)

The most common days for homicide were Saturdays followed by Sundays in all four major cities where the NIMSS had full coverage. Overall, more violent deaths occurred between 20h00 and 23h00 (27 percent) than any other three-hour period, and again this evening peak was apparent in all four cities.

Police data reveal considerable variations in the rate of homicides across provinces from a low of 12.2 per 100,000 population in Limpopo 2010/2011 to a high of 47.3 in the Eastern Cape (Table V). Urbanisation is considered to be a key factor in driving high rates of violent crime (Burton, Du Plessis et al. 2004, United Nations Office on Drugs and Crime [UNODC] 2005), which could explain the substantial variations in provincial injury burdens, as provinces with more urban-based populations have higher injury rates. The fifteen police stations reporting the most homicides comprised a mixture of inner city and township stations with most also being in and around Johannesburg, Cape Town and Durban. These police stations (from most recorded murders to fewest) were Nyanga, Inanda, Gugulethu, Mtata, Umlazi, Khayelitsha, Plessislaer, Tembisa, Katlehong, Empangeni, KwaZekele, KwaMashu East, Moroka, Ivory Park, Kraaifontein (South African Police Services 2011). The murder rates also indicate a fairly consistent decrease year-on year, which provides one possible explanation for the apparent decline in non-natural deaths described in the death certification data described in the section 1.1 of the preceding chapter.

Table V. Police murder rates per 100,000 by province, 2003/4 – 2010/11

	2003/4	2004/5	2005/6	2006/7	2007/8	2008/9	2009/10	2010/11
Eastern Cape	48.6	48.6	53.2	52.6	51.1	49.5	48.4	47.3
Free State	30.5	30.7	29.5	32.2	29.7	31.6	31.4	34.1
Gauteng	48.8	41.6	38.8	40.8	38.9	37.9	32.7	29.1
Kwazulu-Natal	53.9	51.1	49.9	50.4	47	47	40.4	35.2
Limpopo	12.9	13.8	12.9	13.9	12.9	14.2	14.6	12.2
Mpumalanga	30.4	31.9	25.4	24.8	23.6	25.1	24.3	20
North West	25.9	23.9	22.8	24.4	24.3	25.1	21.5	23.2
Northern Cape	40.4	38.1	36.4	38.1	38.3	36.5	33.2	31
Western Cape	63.1	58.7	59.2	60.7	58.6	44.6	42.4	44.2
RSA	**42.7**	**40.3**	**39.6**	**40.5**	**38.6**	**37.3**	**34.1**	**31.9**

Source: South African Police Services (2011)

The SAPS data were also supported by the MRC's provincial estimates of mortality in 2000 with the Western Cape and Gauteng (74 and 72 per 100,000 population respectively), the two most urbanised provinces, reporting the highest homicide rates. Homicide rates were also high in the Mpumalanga, KwaZulu-Natal and the Eastern Cape (68, 59 and 56 per 100,000 population respectively), compared to the Free State (47 per 100,000 population) and Limpopo, the Northern Cape and the North West Province (all 50 per 100,000 population) (Bradshaw, Nannan et al. 2004). It is important to note that although the ranking was similar it was clear that despite the decrease suggested by the SAPS figures, the overall rate estimated by the MRC in 2000 (67 per 100,000 population) was significantly higher. Furthermore, the MRC rate was age standardised using the World Standard population as a benchmark, which, due to the relatively large young adult population in the high-risk group in South Africa, suggests that the crude rate would have been considerably higher.

The NIMSS data showed that as well as the provincial variation suggested by the estimates of provincial mortality there were also substantial differences in city homicide rates between the four cities with full coverage. In 2004, for example, the age standardised homicide rates for Durban (55 per 100,000) and Cape Town (54 per

100,000) were considerably higher rates than those for Johannesburg (40 per 100,000) and Pretoria (26 per 100,000) (Matzopoulos 2005).

Is violence in South Africa increasing or decreasing and what are the costs?

The South African Police Service (SAPS) have reported a consistent decline in homicide from 1994 to 2012 (Table II – section 1.1) and, over a shorter time period from 2001 to 2005, the NIMSS showed substantial reductions in age standardised homicide rates in three major cities where the NIMSS had full-coverage: Cape Town, Durban and Johannesburg (Prinsloo 2007). Most of the decrease in the rate of fatal violence might be ascribed to a decrease in the rate of firearm homicide, which although encouraging, does not point to a decrease in the incidence of violence as evidenced by trends in other categories of violent crime, but rather that fatal outcomes are less likely in the event of violence due to decreasing firearm use.

Nevertheless, it should also be noted that homicide rates are still much higher in South Africa than in most other regions of the world. In addition, mortality figures are likely to under-represent the actual magnitude of the problem. First, injuries from violence afflict a younger population cohort than most non-communicable diseases (e.g. chronic conditions associated with diseases of lifestyle) and some infectious diseases and, consequently, account for a larger percentage of premature deaths than evidenced by mortality rates based solely on counts. Second, as mortality rates only reflect the number of people who die from a specific cause, they ignore the often significant burden imposed on injury survivors living with physical disabilities or mental illnesses and their next of kin. The WHO includes the terms ‘maldevelopment or deprivation’ in their definition of violence, which encompass a wide range of psycho-social outcomes. Among these are diverse psychological responses that can lead to behavioural and emotional problems, such as post traumatic stress disorder and many other psychological outcomes, which have also been implicated as enablers for continued cycles of violence in studies that suggest that victims of violence are likely to become perpetrators of violence themselves (Felitti, Anda et al. 1998, Ellsberg, Jansen et al. 2008, Widom 1989).

Other indirect effects include the contribution of violence to premature mortality from a range of other causes (Matzopoulos, Bowman, Butchart, and Mercy, 2008) and the effect of violence on development more broadly (Bowman, Matzopoulos et al. 2008). For example, evidence from high-income countries has suggested an association between child sexual abuse and a range of psychiatric disorders (Andrews, Corry et al. 2004). In addition, several studies have explored the negative health sequelae of intimate partner violence, with one Australian study that assessed depression, suicide, anxiety and panic disorders; alcohol, drug and tobacco abuse; eating disorders; and high-risk sexual behaviour spread throughout a person's lifetime concluded that intimate partner violence contributed 9 percent to the total disease burden among women aged 15 to 44 years (*The health costs of violence: measuring the burden of disease caused by intimate partner violence: a summary of findings* 2004). In addition high rates of violence may have deleterious and chronic effects on mental health at a population level and affect lifestyle choices, such as the use of public transport or health-seeking behaviour (Matzopoulos, Bowman et al. 2008)

As regards development, high rates of violence in a community reduce property values and undermine the growth and development of business (Greenbaum, Tita 2004, Tita, Petras et al. 2006, World Bank 2006), thus contributing to the very inequalities and concentrations in poverty that play a role in causing violence. The social toll of violence is further exacerbated by economic costs that represent formidable threats to fiscal growth and development (Bowman, Matzopoulos et al. 2008). Poverty contributes to high levels of violence by weakening intergenerational family and community ties, control of peer groups and participation in community organisations (Wilson 1987, GHRI (Global Health Research Initiative) 2005), especially in the context of economic inequality (Unithan, Whitt 1992, Fajnzylber, Lederman et al. 2002, Nafziger 2006), and especially when geographically concentrated.

A recent study by Alda and Cuesta ((2010), which used accounting methodology to provide a comprehensive estimate of the cost of crime, showed that the aggregated costs in South Africa amounted to US$22.1 billion or 7.8 percent of GDP in 2007 (R155 billion at an exchange rate of R7:$1). Health costs accounted for just a third of the total costs, with institutional costs for government agencies that combat crime (the police, correctional services and the justice system) accounting for another third and the rest accruing to the costs of private security and economic costs (in the form of averted Foreign Direct Investment) and transfers (the cost of material transfers from legitimate private owners to thieves). Estimates were on a par with those for other low to middle income countries in Latin American with similar crime levels to South Africa, such as Colombia, Brazil or Venezuela, where estimated costs ranged from 5 percent to 15 percent of GDP.

2.2. Risk factors for violence

The *World report on violence and health* utilises the public health approach to identify risk factors and also as a basis for prevention. This provides a framework within which many alternative disciplinary approaches can be incorporated, including medicine, sociology, epidemiology, psychology, criminology, education and economics (Dahlberg, Krug 2002). It is used extensively by the Global Campaign for Violence Prevention undertaken by the Violence Prevention Alliance, a network of WHO Member State governments, nongovernmental and community-based organisations, and private, international and intergovernmental agencies (*Milestones of a global campaign for violence prevention 2005: changing the face of violence prevention.* 2005), that aims to consolidate links with its public health, human rights-based and criminal justice constituents to provide a more holistic prevention response.

The basic tenet of the public health approach is that violence manifests like any other disease or health problem: it has a human host (or victim) with an inherent risk profile, there is an agent (perpetrator) that acts violently, causing injury, and there are a range of environmental factors (social as well as physical) that either act as protective barriers or increase the risk of exposure to violence. As such, injuries resulting from violence are predictable rather than random events and hence preventable.

In the *World report on violence and health* both risks and preventive strategies are conceptualised according to an ecological model, which expands on the simplistic host-mechanism-environment triad and has already been applied to child abuse (Garbarino, Crouter 1978), youth violence (Garbarino 1985), intimate partner violence (Chaulk, King 1998) and abuse of the elderly (Schiamberg, Gans 1999). This model is also congruent with the health promotion approach outlined in the Ottawa Charter. It shifts the responsibility for health from the individual to the creation of an enabling environment that supports healthy behaviour (Ottawa Charter for Health Promotion, 1986) and thus prevention efforts should ideally be directed upstream to the population-level to maximise incremental benefits for the largest number of people (Dahlberg and Krug, 2002).

There are several different forms of the ecological model, but the basic tenet is that it considers individuals as being nested within several interactive systems (Ward, Artz et al. 2012). In the *World report on violence and health* the first level of the ecological model includes factors that explain an individual's behaviour: demographic and biological factors such as age and sex and intellectual capability, as well as personal and behavioural characteristics such as addictive or aggressive behaviour. The next level describes the effects of social relationships either in relation to the family structure or with friends and acquaintances. The third level explores the characteristics of the different social settings in the community in which violent interactions take place (at work, in school, etc.). The fourth level refers to the different societal factors that allow a climate of violence, e.g. cultural norms that allow violence for conflict resolution, that entrench male dominance, that support the use of excessive force or that maintain social inequality (Dahlberg and Krug, 2002). Ward et al. depict the individual as experiencing the influences of a micro-system (the relationship factors in the *World report*), exo-system (the community factors) and a macrosystem (the societal factors) (Ward, Artz et al. 2012). In this review the four ecological levels of the *World report* are applied, with one additional stratification of individual into biological and behavioural risks as per Figure 2.

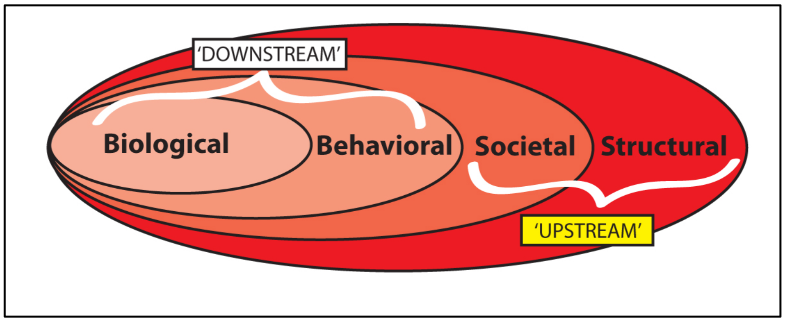

Figure 2. Ecological model for understanding violence

Source: Western Cape Burden of Disease Reduction Project 2008

Demographic risk factors

In terms of the ecological model described above, age and sex are the principal demographic risks. Males are at greater risk of being killed or injured as a result of violence, and are also more frequently the perpetrators of violence. In South Africa, males were disproportionately affected by homicide, which was the second leading cause of premature mortality among males and seventh among females in 2000. Homicide rates increase sharply from 15 years of age, peaking in the 25 to 29 and 35 to 39 age groups for men and women respectively (Bradshaw, Groenewald et al. 2003).

In 2004, the NIMSS recorded six male deaths due to interpersonal violence for every female death (Matzopoulos 2005) compared with the global average of 3.4 (Mathers, Inoue et al. 2002). Rates among both sexes were considerably higher in South Africa than the global averages: more than eight times greater among males and five times greater than the global average among females (Norman, Matzopoulos et al. 2007). The deaths followed a similar distribution in South Africa as elsewhere, but among males the high risk categories spanning 15 to 44 years of age accounted for a larger proportion of deaths. Among females there was a disproportionately high number of fatalities in the 30 to 44 year age category as well as among women aged older than 60 years (Norman, Matzopoulos et al. 2007).

Males also account for a greater proportion of non-fatal cases presenting to health facilities. The male to female ratio was far more pronounced at the tertiary level (6 males for every female injury) (Schuurman, Cinnamon et al. 2011) than at the primary level (1.5 males per female) (Govender, Matzopoulos et al. 2012). Whereas males are mainly the victims of fatal and severe physical violence, women are more frequently the targets of sexual assaults and domestic abuse that have a relatively larger proportion of non-fatal outcomes. As described in section 2.1 of this chapter, children constitute a large proportion of victims of violence generally and of sexual abuse in particular.

Behavioural risks

Behavioural risks for violent and aggressive behavior include individual personality characteristics and quality of social interactions, which are aggravated by environmental factors. Problems experienced in early childhood development can predispose youth to violent behavior (Karr-Morse, Wiley 1997). These childhood problems include hyperactivity, impulsiveness, poor behaviour and attention problems including early onset conduct problems such as aggression and oppositional, disruptive or destructive behaviours. Diet and exposure to environmental lead may affect aggressiveness and risk-taking behaviour (Gesch, Hammond et al. 2002, Schoenthaler, Amos et al. 1997, Nevin 2000).

Alcohol and substance abuse impact primarily at the behavioural level and their association with trauma, particularly relating to violence, is well documented. Alcohol accounts for 25 - 50 percent of intentional injuries (Parry, Dewing 2006, Shultz, Rice et al. 1991, Single, Robson et al. 1998, English, Holman et al. 1995), and is associated with child abuse (Strauss, Gelles 1986, Golding 1996)and intimate partner violence (Black, Schumacher et al. 1999, Rodgers 1994, Johnson 1996). In South Africa, more than half of the patients presenting with injuries from violence tested positive for alcohol use (Plüddemann, Parry et al. 2004) and more than half of the victims of fatal violence recorded in the NIMSS test positive for alcohol (Matzopoulos 2005). The Demographic and Health Survey data suggest that alcohol use significantly increased the risk of being becoming the victims of violence (Doolan 2006).

There are several indications pointing to the social nature of violent crimes involving alcohol in South Africa. Victims of fatal violence that died as the result of sharp force injuries had the highest proportion of alcohol-positivity (72 percent) as well as the highest mean blood alcohol concentration among alcohol positive fatalities (0.19g/100ml) (Matzopoulos 2005). One study described how men used alcohol in a premeditated way to gain courage to beat partners (Jewkes, Vundule et al. 2001). Cape Town had the most distinct peak in weekend incidence of homicide and recorded the highest percentage of alcohol positive deaths. Levels of intoxication were also significantly higher than in Johannesburg ($p<0.01$) and Durban ($p<0.01$) (Matzopoulos 2005).

Information on drug usage in relation to violence was more difficult to obtain, because drug testing was not performed routinely during post mortem investigations mainly due to the cost. Trends in the types of drugs that are popular also vary and cross-sectional studies soon become dated in relation to the drug of choice. Nevertheless, one study showed self-reported cannabis use at between 22 percent and 28 percent of arrestees that committed violent offences (Taylor, Brownstein et al. 2003), and another conducted among arrestees across eight police in Cape Town, Durban and found that 46 percent of murder suspects tested positive for drugs (Parry, Plüddemann et al. 2004). Similarly, urinalysis from a hospital-based study of trauma victims in three South African cities between 1999 and 2001 found a high prevalence of drug usage among cases that presented for injuries due to violence from a low of 34 percent in Port Elizabeth to a high of 66 percent in Cape Town in 2001, particularly cannabis and mandrax (methaqualone) (Parry, Plüddemann et al. 2005).

The association between drug usage and the risk of being a victim of violence was also higher in Cape Town, as shown in the studies of patients presenting to trauma units in Cape Town, Durban and Port Elizabeth (Plüddemann et al. 2004; Parry et al. 2005). The percentage of cases testing positive for drugs ranged from a low of 41 percent in 2000 to 66 percent in 2001 in Cape Town, compared to 45 percent to 50 percent in Durban and 34 percent to 44 percent in Port Elizabeth (Parry et al. 2005). However, Port Elizabeth had consistently higher percentages of patients testing positive for alcohol ranging from a low of 73 percent in 2000 to a high of 90 percent in 1999, compared to 58 percent to 65 percent in Cape Town and 43 percent to 58 percent in Durban (Plüddemann et al. 2004).

Relationship risks

These begin with early childhood family relationships including large numbers of children, poor family cohesion, single-parent households, young mothers, partner and child abuse and harsh punishment practices within the family (National Research Council 1993, Klevens, Bayón et al. 2000, McCord 1979, Mercy, Butchart et al. 2002, Eron, Huesmann et al. 1991, Farrington 1998, Madu, Peltzer 2000).

Exposure to adverse experiences in childhood is also associated with a wide range of health conditions and behaviours later in life. As regards violence and aggressive behavior specifically, adverse exposures include experiencing physical and sexual abuse and witnessing violence and parental alcohol abuse (Whitfield, Anda et al. 2003, Felitti, Anda et al. 1998, Edwards, Fivush et al. 2001, Edwards, Holden et al. 2003, Dube, Anda et al. 2001, Dube, Anda et al. 2002, Dube, Anda et al. 2002, Dube, Anda et al. 2005, Dube, Anda et al. 2001, Dube, Miller et al. 2006, Hillis, Anda et al. 2001, Dong, Anda et al. 2003, Dong, Anda et al. 2004, Anda, Felitti et al. 2001, Anda, Felitti et al. 2006, Anda, Brown et al. 2007, Chapman, Whitfield et al. 2004). The outcomes include later involvement in intimate partner violence (Anda, Felitti et al. 2001, Whitfield, Anda et al. 2003), household dysfunction (Dube, Anda et al. 2001, Dong, Anda et al. 2003, Dong, Anda et al. 2004, Felitti, Anda et al. 1998), problematic alcohol and other drug use (Anda, Felitti et al. 2001, Anda, Whitfield et al. 2002, Dube, Anda et al. 2001, Dube, Miller et al. 2006, Dube, Felitti et al. 2003), mental health problems (Anda, Whitfield et al. 2002, Chapman, Whitfield et al. 2004, Edwards, Holden et al. 2003), teen pregnancy (Anda, Felitti et al. 2001) and risky sexual behavior (Hillis, Anda et al. 2001). This has also been demonstrated in South Africa. One quarter of men surveyed in three municipalities in the Western Cape had witnessed abuse of their mothers and these men were three times more likely to abuse their partner than other men in the study (Abrahams, Jewkes 2005). Household dysfunction is also evident in that half of all women murdered in South Africa were killed by an intimate partner (Mathews, Abrahams et al. 2004). Traditional gender and *social norms* are also associated with female partner abuse (Heise, Garcia-Moreno 2002).

Societal risks

Outside the familial setting, having violent peers is a risk factor for violent and sexually abusive behaviour and substance abuse among youth (Butchart, Phinney et al. 2004, Dunkle, Jewkes et al. 2006). Gangs, drugs, guns and high violence rates engender violence in residents with negative mental health implications for children (Farrington 1998, Ensink, Robertson et al. 1997). Reduced *social capital*, manifesting as low social cohesion and interpersonal mistrust, has been linked with higher violence rates (Wilkinson, Kawachi et al. 1998). A Cape Town study found that 32 percent of pregnant adolescents and 18 percent of matched controls had been forced into their first sexual experience (Jewkes, Vundule et al. 2001). Abuse of women is aggravated by the existence of armed conflict where violence is an everyday occurrence (Counts, Brown et al. 1992). In the Western Cape, 38 percent of male and 8 percent of female learners admitted carrying weapons in the past 6 months (Medical Research Council 2002). The high rates of fatal violence in Cape Town were also unusual in that sharp-force injuries featured more prominently than in the other cities and rates were higher in younger age groups. This indicated a high prevalence of community and youth violence and the city also has a history of social problems associated with street crime and gangs, which comprise an estimated 90,000 members in the Western Cape (Cerda 2002).

The subtext for much of this societal dysfunction can be attributed to the substantial disparities in socioeconomic status and income that continue to manifest along racial lines as a result of apartheid. The relationship between inequality and crime has been explained using the concept of relative deprivation, which breeds social tensions (Fajnzylber et al. 2004), and it is understood internationally that violence is more concentrated in areas of poverty and deprivation (Butchart et al. 2004). Relative deprivation refers not only to the differences between communities, but also the relative socioeconomic position of the household within a community. A study of adolescent boys and girls outside Durban found that risk factors for sexual violence included poverty, low self-esteem, traditional notions of masculinity, the normalisation of inter-personal violence and weak adult and community protective shields (Petersen, Bhana et al. 2005).

Two important indicators of socioeconomic position are employment and education. The primary and high school drop-out rates for Africans has been estimated as being as high as 72 percent and 24 percent of African adults have never attended school at all (Flisher and Chalton 1995). Flisher and Chalton (1995) summarise some of the adverse consequences of not completing schooling for the individual as: (1) having low levels of academic skills, (2) reduced probability of steady employment or receiving adequate income, (3) poorer mental and physical health, (4) increased use of psychiatric and mental health services due to drug-related problems; and at a societal level as:(5) forgone tax revenues, (6) increased demand for social services and (7) increased crime rates. Research conducted in Chile, Egypt, India and the Philippines showed that female education and household wealth as being protective factors against intimate partner violence (Bangdiwala, Ramiro et al. 2004). In South Africa a cross-sectional study in three provinces indicated that whereas education was a protective factor other measures of socioeconomic position were not (Jewkes, Penn-Kekana et al. 2001).

Structural risks

There is considerable variation in homicide rates internationally, with more than half of all homicides occurring in just one-quarter of the world's nations, which represent just 18 percent of the global population (Eisner & Nivette, 2012). South Africa is among these countries, which also include parts of Latin America (e.g. El Salvador and Colombia), and Asia (e.g. Kazakhstan and Russia). Structural risks include the major social and demographic changes, such as migration, urbanisation and modernisation that are associated with increased interpersonal violence (United Nations Office on Drugs and Crime [UNODC] 2011, Burton, Du Plessis et al. 2004, Mercy, Butchart et al. 2002, Messner 1988, Groenewald, Bradshaw et al. 2007). Poverty, deprivation and inequality are strong determinants (United Nations Office on Drugs and Crime [UNODC] 2011, Butchart, Phinney et al. 2004, Krahn, Hartnagel et al. 1986, Sampson, Raudenbush et al.

1997) and urban living with increased population density, degraded environment, overloaded infrastructure, and stretched service delivery is associated with higher injury and homicide rates (Santosa, Barcellosa et al. 2006).

In a meta-analysis of the predictors of crime, Nivette (2011) identifies inequality, high levels of state corruption, low investment into public health and education, low state stability, and histories of ethnic, ideological or religious tensions, as the key national characteristics within these countries that support high homicide rates (Nivette, 2011). Nivette and Eisner (2012) have also shown that homicide rates are sensitive to legitimacy, as defined by a state's capacity to obey its own laws (legality), the degree to which civil and political values coincide (justification), and the level of behavioral consent among its people (consent)(Nivette & Eisner, 2012).

Along with the substantial demographic, behavioural and societal risks that prevail in South Africa the structural risks are also notable. South Africa is not only one of the most violent countries in the world, but also one of the most unequal with a Gini coefficient - a measure of income inequality - last reported at 63.1 in 2009 by the World Bank (2012). At a local level spatial analysis of the health districts within Cape Town showed that the highest rates of homicide were recorded in the relatively impoverished sub-districts of Nyanga (132 per 100,000 population) and Khayelitsha (120 per 100,000 population). The rates were double the citywide average of 66 per 100,000 and three times the rate recorded in the city centre (42 per 100,000) (P. Groenewald et al., 2010). These discrepancies would likely have been more pronounced had small area data been available to disaggregate informal housing from more established residential areas, as local health facility-based pilot studies have also shown a clustering of injury events at more localized levels (Schuurman et al. 2011; Govender et al. 2012).

The effect of migration is also an important factor to consider in understanding the relationship between urbanisation and high rates of violence, as homogeneous, poor populations tend to have lower rates of violence than heterogeneous socio-economically unequal populations (Kawachi, Kennedy et al. 1997, Szwarcwald, Leal 1998).

Unprecedented urban growth is an important global issue, with 40-60% of urban growth in developing countries resulting from migration and spatial expansion of cities into rural areas (Montgomery, 2008). Projections indicate that the largest rates of urban population growth are expected in Africa and Asia and it is estimated that between 2000 and 2030 the urban populations of these areas will have doubled. Rapid urban population growth in many cities of low and middle-income countries has outstripped the ability of governments to provide housing, and basic services (water, sanitation and waste removal) and essential services (access to heat, education and housing). Furthermore, the supply of quality employment is also insufficient to meet the growing demand with the proportion of the urban poor increasing faster than the urban population growth rate (Cohen, 2006; Montgomery, 2008).

In the last two decades internal coinciding with the relaxation of the apartheid-era Group Areas and Influx Control legislation and cross-border migration, due to civil unrest and economic instability in countries to the north of South Africa, have been the catalyst for South Africa's rapid urbanisation and dramatic expansion in the size of informal housing settlements on the urban periphery. The resulting hardships in securing dwellings, services and scarce resources, competition for jobs and rising unemployment as well as the inability of apartheid era infrastructure to cope with this rapid urbanisation are well-documented in the social science literature and beyond scope of this review. However, it should be noted that the first wave of migrants from South Africa's rural areas has been young men seeking employment, which has dramatically altered the demographic profile of South Africa's major cities and towns. Gauteng in particular has a much larger male population in the 20 to 44 age group than the national average, and this group is also the most at-risk group for violence, either as perpetrators or as victims[6]. This has placed a considerable burden on already stressed social infrastructure and services, particularly in

[6] Note that the age standardised rates from the NIMSS adjust the age profiles of the different cities to a common standard. As a result, the age standardised rate for a city like Johannesburg with a large proportion of young adults, is somewhat lower than the crude or actual rate.

the peri-urban communities that were the primary sites for the xenophobic violence that afflicted the country in May 2008 (Kapp, 2008).

2.3 Violence prevention

In terms of prevention, the public health approach typically defines three levels: primary, secondary and tertiary, each of which refers to the timing of the prevention response. Primary prevention focuses on addressing risks and antecedents of violent and aggressive behaviour in an attempt to reduce the likelihood of violence occurring. This might be directed at potential perpetrators by curbing tendencies towards violent behaviour, or potential victims by reducing the factors and characteristics that predispose them to victimisation. Secondary prevention focuses on the immediate response to violence, such as emergency medicine including pre-hospital care for victims, and retribution through the criminal justice system. Tertiary prevention is aimed at mitigating the long-term effects of violence-related injury and the rehabilitation and re-integration of offenders (Dahlberg and Krug 2002).

Strategies to contain violence through policing and criminal justice can be allocated to primary (e.g. visible policing to curtail criminal acts), secondary (e.g. the arrest and prosecution of suspects following acts of violence) or tertiary response (e.g. victim support and empowerment and the reintegration of offenders). However, (Van der Spuy 2001) recognises several disparate crime prevention strategies in South Africa that draw on competing principles. For example, rehabilitation and restorative justice is considered for young offenders, whereas a more punitive approach is advocated for perpetrators of gender violence or child abuse. There are also disparities in theories on crime causation and the enforcement response, from more empathic policing to ‘zero-tolerance’. Application of public health principles necessitate the collection and analysis of various outcome measures to ensure that prevention policies are informed by evidence of effectiveness, which is the norm in progressive policing jurisdictions internationally.

The human rights approach is of particular relevance in South Africa due to the prominent role played by human rights activists in the struggle against Apartheid. The human rights approach recognises violence as a human rights issue and focuses on the state's responsibility and legal obligation to address its prevention and effects, which requires that national laws, policies and practices take into account factors such as gender relations, religious beliefs, sexual preference and race (Gruskin and Butchart 2003). Among the more obvious rights invoked are the right to bodily integrity, the right of a person to safety and security and freedom from violence, but broader implications include gender equality, self determination, social, economic and cultural rights. By showing how risk factors are distributed through the ecological context and linking violence with risk factors such as economic, social and gender inequalities, unemployment and inadequate social protection and educational opportunities, the human rights approach is frequently used to drive law reform.

In South Africa the Right to Safety is implied through the Right to Life in the Bill of Rights (Constitution of the Republic of South Africa Act 108 of 1996) and within the Bill of Rights are numerous provisions that outline the type of environments, services and support that the Constitution advocates. For example provisions that may have a bearing on violence against children include Section 24 - the right to live in an environment that is not harmful to the child's health or well-being; Section 27 - the right to health care services and the right not to be refused emergency medical treatment respectively; and Section 28 - the right of the child to be protected against abuse and neglect. Furthermore, South Africa has also been a signatory to numerous international treaties and established various offices to ensure that basic rights are applied, such as the National Children's Rights Committee and the National Programme of Action for Children (Van der Merwe and Dawes 2007). However, the Right to Safety is only included implicitly and if South Africa is to realise a significant improvements in public safety, it needs to embrace at a macro-level policies that support safer environments and be reconciled with the public health approach that typically holds the interests of the population in higher regard than those of an individual, strengthening the basis for protection against violence.

In their guide to implementing the recommendations of the *World Report on violence and health*, Butchart et al. (2004) maintain that violence prevention requires comprehensive intervention strategies involving all sectors of society to address core sets of underlying causes and risk factors, including governments, NGOs and civil society, as well as the general public and the private sector. Butchart et al. (2004) highlight several key strategies for promoting primary prevention:

1. Investing in early interventions as programmes targeted at the early development stages of childhood show greater promise than those directed at adults;
2. Increasing positive adult involvement in the monitoring and supervision of children and adolescents as a warm, supportive relationship with parents or other adults is protective against anti-social behaviour;
3. Strengthening communities through e.g. reducing the availability of alcohol or improving childcare facilities
4. Changing cultural norms so that positive norms such as those that promote equality for women or respect for the elderly are promoted and negative norms such as those that associate violent behaviour with masculinity, foster racism, classism, and sexism are countered;
5. Reducing income inequality by investing in programmes and policies that reduce income inequality, or minimise its impact; and
6. Improving the efficiency and resource base of the criminal justice and social welfare systems.

In Table VI these six strategies were used as a basis for the categorisation of interventions for violence prevention that were described in three international reviews (Butchart, Phinney et al. 2004, Dahlberg, Butchart 2005, Mercy, Butchart et al. 2002), as well as information gleaned from the *Violence prevention evidence base*, an online resource developed and maintained by the Centre for Public Health at Liverpool John Moores University, a WHO Collaborating Centre for Violence Prevention (Centre for Public Health, Liverpool John Moores University 2011).

The criteria for effectiveness included: evaluations using a strong research design; evidence of a significant prevention effect; evidence of a sustained effect (i.e. the effect extends beyond the duration of the programme); and replication of a programme with demonstrated preventive effects across different settings. In the tabulation, the effective interventions are underlined and where there is disagreement between the different sources as to the strength of evidence, the most recent source is favoured. The remaining interventions were described as ‘promising’ in that they had been evaluated with a strong design and had some evidence of effectiveness, but required further testing. In Table VI the six strategies are ordered from distal/upstream to proximal/downstream as in the ecological model and within each of the six strategies the interventions are similarly ordered. In other words, priority was accorded to strategies and programmes targeting societal, followed by community, relationship and then behavioural and demographic factors.

Table VI: Promising and effective interventions for violence prevention*

Possible Violence Interventions	Ecological level
REDUCING INCOME INEQUALITY ➢ Job-creation programmes for the chronically unemployed for ages 20 and older ➢ Poverty reduction ➢ Housing density and residential mobility programmes ➢ Micro-finance projects for women	Distal
IMPROVING THE CRIMINAL JUSTICE AND SOCIAL WELFARE SYSTEMS ➢ Easier access to social support for women and families ➢ Further legislation to criminalise the maltreatment of children, intimate-partner violence, and elder abuse ➢ Mandatory arrest for intimate partner violence ➢ Improve services for children who witness violence; ➢ Safe havens for children on high-risk routes to and from school ➢ Shelters and crisis centres for battered women and elder abuse victims ➢ Improved police and judicial systems to ensure more equitable access, protection, and legal recourse for victims, witnesses and suspects, and more efficient investigation and judicial procedures	Distal
➢ Treatment programmes for victims of maltreatment for children aged 0 to 3 years ➢ Services for adults who were abused as children for ages 20 and older ➢ Treatment for child and intimate-partner abuse offenders for ages 20 and older ➢ Screening by health-care providers for the identification and referral of high-risk youth, battered women, victims of elder abuse, child maltreatment, and sexual violence	Proximal

CHANGING CULTURAL NORMS ➢ Mobilise women's community networks to challenge prevailing aggressive norms and beliefs to reduce tolerance of violence, and to teach perpetrators to fear the consequences of their actions ➢ Work with young men to change their attitudes and behaviour with regard to gender-based violence and violence in general ➢ Campaigns to increase public awareness of child maltreatment ➢ "Name and shame" intimate-partner violence offenders ➢ Adult recreational programmes ➢ Community policing ➢ Reduce the glorification of violence in popular media, including television, film and computer games ➢ Public information campaigns to promote pro-social norms for children aged 9 to 11 years ➢ Change cultural norms that support violence, such as those that support male dominance over females; parental dominance over children; and violence as a means of conflict resolution	Distal
➢ Encourage and expand life-skills training programmes ➢ Reduce unintended pregnancies (aimed at preventing violence against children aged 0 to 3 years) ➢ Recreational programmes for children aged 3 to 19 years ➢ Peer mediation or peer counselling for children aged 12 to 19 years	Proximal
STRENGTHENING COMMUNITIES ***Alcohol*** ➢ Implement a coherent liquor-outlet policy which brings informal outlets into the regulated market; ➢ Community mobilisation against alcohol misuse ➢ Norms/guidelines for school-based programmes based on best practice ➢ Product restrictions, e.g. on size of packaging and clearer, legible labels regarding content ➢ Restrict products that appeal to youth ➢ Reduce alcohol availability for ages 12 years to 19 years ➢ Establish integrated programmes that address alcohol and substance abuse alongside other violence-prevention initiatives ➢ Advertising and promotional restrictions	Distal
➢ Pilot and implement brief interventions for high-risk and hazardous drinkers	Proximal
Education and childcare ➢ Programmes which provide youths with incentives to complete secondary schooling; ➢ School-based prevention programmes aimed at reducing date-related violence ➢ Introduce child-protection service programmes ➢ Improve school settings for children ➢ Install metal detectors in schools for children aged 3 to 19 years	Distal
➢ Introduce social development programmes for children between the ages of 3 and 19 years ➢ Encourage academic enrichment programmes for children aged 12 to 19 years ➢ Introduce temporary foster-care programmes for chronic delinquents for children aged 12 to 19 years	Proximal
Firearms ➢ Enforce longer waiting periods for firearm purchases ➢ Hold gun-owners liable for damage caused by gunfire ➢ Promote the safe storage of firearms and other lethal weapons ➢ Enforce laws which prohibit the illegal transfers of guns to youth	Distal
INVESTING IN EARLY CHILDHOOD EDUCATION ➢ Lead monitoring and toxin removal ➢ Increased access to pre- and post-natal care for children aged 0 to 3 years ➢ Multi-context, long-term interventions that impact on multiple dimensions of a child's environment ➢ School-feeding schemes to ensure adequate nutrition in all grades throughout the schooling years	Distal
➢ Introduce therapeutic foster care for children aged 0 to 3 years ➢ Implement preschool enrichment programmes for children aged 3 to 11 years ➢ Introduce home visitation aimed at reducing violence directed at children aged 0 to 3 years ➢ Provide training for young parents aimed at reducing violence among children aged 0 to 5 years ➢ Hospital-based, parent education programme to reduce the incidence of abusive head injuries	Proximal

among infants and children ➢ Provide mentoring for children aged 3 to 11 years ➢ Implement school-based child-maltreatment prevention programmes for children aged 3 to 11 years	
INCREASING POSITIVE ADULT INVOLVEMENT	
➢ Incentives for young adults and high-risk youths to complete high school and post-secondary education or vocational training	Distal
➢ Provide mentoring for children aged 12-19 years ➢ Provide family mentoring for families with children aged 12-19 years ➢ Introduce home-school partnership programmes to promote parental involvement for children aged 3 to 11 years ➢ Provide after-school programmes to extend adult supervision for children such as wilderness programmes and other outdoor programmes for youth at risk	Proximal

* Interventions with strong evidence of effectiveness are underlined.

It should be noted that the effectiveness of policing and the criminal justice system more generally for social protection and crime and violence prevention is one of the key strategies identified by Butchart et al for reducing violence levels. The effective apprehension of murder suspects and successful prosecution of perpetrators and state provision of social welfare to shelter and protect victims has substantial violence-reducing impacts (Fajnzylber, Lederman et al. 2002, Pampel, Gartner 1995, Messner, Rosenfeld 1997), but a cursory review of current national violence prevention strategies in South Africa reveals an over-reliance on downstream interventions to reduce the short-comings of the criminal justice sector, such as through the funding of private security companies, effectively a downstream intervention compared to other more upstream solutions that are available through more effective social responses to violent crime. These in effect are the immediate responses to a dysfunctional criminal justice system. Downstream interventions can be applied with immediate effect, whereas upstream interventions such as those that create employment and reduce wealth disparities are more difficult to apply over a longer period and also require a longer period to demonstrate their effects.

Prevention is hence security focussed either through increased spending on private security systems and personnel or through increased quotas of national and metropolitan police officers. This security focus has often been at the expense of corresponding investment in social welfare services. For example, Matzopoulos et al (2010) draw attention to the implementation of the country's Domestic Violence Act, which has an overreliance on criminal justice measures, whereas it ideally required an intersectoral response to span the justice, health, welfare and social services (Mathews, Abrahams 2001, Parenzee, Artz et al. 2001).

When funding has been provided for social welfare services, this has also frequently focussed on downstream programmes and interventions in response to violence. For example, funding for the Children's Amendment Act no. 30884 of 2007 has predominantly targeted the medical care of rape survivors even though the Act makes provision for psychological, rehabilitative and therapeutic programmes for children who have been abused (Matzopoulos, Bowman et al. 2010).

There are two key observations from the tabulation in Table VI. First, the small proportion of effective, as opposed to promising, interventions is a consequence of the difficulty in measuring their impact on actual reductions in physical violence. Identifying the drivers of these changes is complicated by the fact that they may result from a complex web of factors that influence individuals and relationships over a long period of time. Typically, it is more difficult to attribute causality to more upstream interventions where the web widens progressively, where there is a concentration of effective programmes at a more down-stream, or proximal, rather than at an upstream or distal level of intervention. This is partly because the former interventions are inherently more amenable to evaluation, impacting more directly as they do on readily identifiable victims or perpetrators of violence. Upstream interventions that target patterns of inequity in respect of social determinants such as income levels, the provision of housing, infrastructure, educational levels, employment, and health expenditure might be expected to have a greater impact. However their impacts are less direct and more diffuse and it is consequently difficult to attribute observed changes in violence rates to upstream interventions.

Consequently there is a bias in the scientific literature towards a more measurable downstream programmatic focus, which avoids the difficulty of analysing numerous interacting determinants of effectiveness. This is especially problematic for settings such as South Africa where there is a substantial burden of violence and where more far-reaching upstream interventions that mitigate a range of social and health problems might be more worthwhile investing in.

Second, studies that measure the effect of interventions on violence reduction are concentrated in HICs. There is a dearth of studies from LMICs and much of this can be attributed to the poor quality of data sources that provide routine and reliable outcome data. Consequently, many evaluations of violence-prevention programmes in LMICs assess the effectiveness of proxies such as changing knowledge and attitudes rather than direct measurements of change in the incidence of injuries (Dahlberg and Butchart. 2005). These challenges are, of course, compounded for upstream interventions in LMICs. Matzopoulos et al (2010) argue that developing the technological infrastructure and human resource capacity required to scientifically assess the effectiveness of upstream interventions should attract national and local government funding, as well as international donor aid. This has until recently been allocated piecemeal to priorities aligned with Millennium Development Goals rather than violence prevention more broadly (Matzopoulos, Bowman et al. 2008, Bowman, Matzopoulos et al. 2008).

2.4. Evaluation of surveillance systems

All of the relevant taxonomies for recording mortality, such as the International Classification of Disease or the definitions of crime or road traffic fatalities as used by criminal justice and enforcement agencies are constructs, which frequently require subjective interpretations by those responsible for determining the manner and cause of death and coding the data. Even the findings of the final arbiter in determining the legal manner and cause of death, i.e. the Inquests Court, may be questionable as magistrates might not always be presented with all of the relevant evidence. Both investigating officers, who are responsible for gathering evidence, and prosecutors, who present and lead evidence in court are notoriously overworked (Lené Burger, personal communication). Therefore, there is no objective criterion or, “gold standard”, from which to validate injury mortality surveillance systems.

In the absence of a “true” measure, the criterion validity of the system cannot be assessed (Streiner, Norman 2006) and so its reliability can provide better indications as to the system’s overall utility. The reliability/repeatability in this case refers to the likelihood that different users of the system (or the same user at different points in time) would assign the same values to key variables when presented with the same set of information describing each fatal event. The validity of the system can be ascertained by the extent to which it yields information that has utility for these users (Streiner, Norman 2006). Similarly, Lyons et al. (2005) suggest that the utility of surveillance systems can be demonstrated through their ability to strengthen the case for intervention by identifying risk factors and by providing injury indicators that will (1) measure the burden of injuries to convey the importance of prevention to policy makers, (2) enable comparison with other areas or countries and (3) measure the change in the burden of injury (Lyons, Brophy et al. 2005, 2005)

In 2001, Burrows assessed the utility of the surveillance data from the NIMSS pilot study described by Butchart et al (2001) for mobilising prevention measures and identified the following uses:

1) Informing and mobilising prevention activities as the data were seen as reliable and unbiased;

2) Influencing policy for which Burrows provided two examples: the Road Accident Fund Commission’s use of NIMSS findings to inform recommendations regarding the payment of compensation and benefits, and the National Crime Prevention Centre using the data to inform the development of a firearm policy;

3) Influencing legislation, in which Burrows highlighted the use of the NIMSS data by Gun Free South Africa in influencing the new Firearms Control Bill, and by Statistics South Africa in their attempts to repeal Act 51 of 1992 that prohibited the registration of the external cause of death;

4) Public awareness and education, for which Burrows cited the use of the NIMSS data in newspaper articles and by agencies including the CSIR, UNISA and the WHO;and

5) Informing resource allocation both within the health services and for injury control programmes, for which Burrows cited the use of the NIMSS data in restructuring plans for mortuaries in South Africa.

In addition, Burrows identified three potential uses that had not as yet been realised:

1) Using the data as a basis for further research;

2) Targeting prevention measures, for which Burrows cited numerous potential uses but no concrete examples; and

3) Evaluating prevention measures by providing baseline and trend data to assess the effectiveness of an intervention over time (Burrows 2001)**.**

This may have been due to the short time-lag between the initial dissemination of the findings and Burrows' evaluation, subsequent to which, the data have been more widely utilised. As regards further research, although many of the NIMSS based studies have remained descriptive (Suffla, Van Niekerk et al. 2008, Mabunda, Swart et al. 2008, Blom, van Niekerk et al. 2011, Burrows, van Niekerk et al. 2010), there have also been several analytic studies (Matzopoulos, Peden et al. 2006, Chokotho 2011). Burrows also noted that there may also have been institutional barriers to the uptake of this information and concluded that there was a responsibility for researchers to assist users of the data in applying surveillance data for the design, implementation and evaluation of prevention programmes. This was supported by the authors of a Pretoria study, where customised city-specific injury reports produced to inform intervention efforts were used in a limited way by mid-level managers. The authors concluded that the effective translation of research data such as those emanating from the NIMSS was contingent on favourable content, contextual, social actor and process influences (Gouveia, Seedat et al. 2011).

In their evaluation of the utility of the first six months of data collection, Butchart et al (2001) applied the criteria of the US Centers for Disease Control (CDC) from their *Guidelines for evaluating the utility of epidemiologic surveillance systems.* This measured utility according to the system's ability to satisfy the following system attributes: (1) simplicity, (2) flexibility, (3) acceptability, (4) sensitivity, (5) positive predictive value[7] and (6) the quality, timeliness, and usefulness of the data (Klaucke, Buehler et al. 1988).

Simplicity refers to the surveillance system's structure and ease of operation. Klaucke et al. (1988) suggested the following measures that could be considered in evaluating simplicity:

a. The amount and type of information required
b. Number and type of data sources
c. Method(s) for transferring data
d. The number of organisations involved in receiving case reports
e. Staff training requirements
f. The type and extent of data analysis
g. Number and type of end-users of the compiled information
h. Method of information dissemination
i. Time spent: (1) maintaining the system, (2) collecting case information, (3) transmitting case information, (4) analysing case information, (5) preparing and disseminating surveillance reports

Flexibility encompasses the surveillance system's adaptability to changing information needs or operating conditions, new diseases and health conditions, changes in case definitions, and variations in reporting sources. This could best be assessed retrospectively by observing the system's response, e.g. in terms of its time, personnel and funding requirements (Klaucke, Buehler et al. 1988).

Acceptability refers to the participation and endorsement of stakeholder individuals and organisations within and external to the sponsoring agency and quantitative indicators would include participation rates, the rate of system implementation, refusal rates and barriers to implementation, the completeness of case report forms and the timeliness of reporting. In the case of the NIMSS the

[7] It should be noted that sensitivity and positive predictive value are both performance measures of criterion validity, but it the CDC's criteria reflect a more limited notion.

external stakeholders included the forensic pathologists, medical practitioners, staff at the mortuaries and MRC and UNISA based researchers receiving, cleaning, reporting and analysing the data.

Sensitivity refers to both the proportion of cases of a disease (in this case fatal injuries) that the surveillance system can detect and also its ability to detect epidemics, noting that a surveillance system with moderate sensitivity can still be useful in monitoring trends if the level of sensitivity is constant.

Positive predictive value was the proportion of identified cases that actually meet the case definition, such as might be assessed through a small validation study.

Data quality was measured according to the completeness, reliability, timeliness and utility of data. It should be noted that in this case, when criterion validity cannot be measured, inter-rater agreement is used as a proxy for validity if test raters are validated against "expert" raters or the ratings of a panel of experts.

The guidelines did recognise that due to the wide variability in the methodology, scope, and objectives of epidemiologic surveillance systems, the importance of each system's characteristics may vary and efforts to improve certain attributes, e.g. a system's sensitivity, may compromise other attributes, such as its simplicity or timeliness. The value of the surveillance system would therefore depend to some extent on the ability of the evaluator to apply a nuanced understanding of the proper balance of each system's attributes and how these combine to affect the usefulness and cost of a system (Klaucke, Buehler et al. 1988).

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CHAPTER 3: REFLECTIONS ON THE UTILITY OF THE SURVEILLANCE SYSTEM AND THE QUALITY OF THE DATA GENERATED

In order to evaluate the utility of the surveillance data, the guidelines developed by the US Centres for Disease Control (Klaucke et al. (1988) described in section 2.4 of the literature review) and applied by Butchart et al. (2001) were revisited and revised based on more recent information.

3.1. Simplicity

Among the measures to maximize simplicity Butchart et al. (2001) described extensive consultation during the system design phase, the utilisation of an easy-to-use case report form with check boxes for most data items, the minimal training requirements for participating staff and the ease-of-use of the customised EpiInfo 6 data entry software (Dean, Dean et al. 1995).

The initial success of NIMSS might have been ascribed to the prioritisation of larger mortuaries in mainly urban areas during the system's pilot phase, which ensured that there were adequate personnel and infrastructural resources to maintain the system. Attempts to expand the system to rural areas were less successful, as evinced by Mpumalanga providing occasional and incomplete data between 2002 and 2005, which prompted the focus on full coverage of major cities. This too was challenging with lesser resourced mortuaries, typically those in black or coloured townships, such as in Mdantsane in East London, New Brighton and Gelvandale (both in Port Elizabeth) and not attached to academic forensic medicine departments at tertiary institutes, often failing to provide complete data.

Another complicating factor was the "participation fee" paid to mortuaries, which set a precedent that was difficult to manage and contain with the rapid increase in the number of participating facilities and caseload from 2001 that coincided with the discontinuation of external funding. Nevertheless, these factors did not compromise the timeliness of the system irrevocably. The research team identified missing data, which were captured by part-time field-workers, and were invariably able to collate national data and publish annual reports before the end of the following year.

In the latest iteration of the surveillance system, the Western Cape PIMSS, non-compliance has been averted, as data collection is now fully integrated into the operational processes of the mortuaries. Data are entered into the Forensic Pathology Service (FPS) information system as part of the routine post mortem data collection and the most important variables are mandatory. Data management and analysis have also been simplified. These were positive aspects of the system to begin with, as the use of numerical coding for most variables minimised the need for coding prior to analysis. The simple descriptive analyses of the pilot phase and in routine reports such as the NIMSS annual report were processed using spreadsheets. Subsequently automated report generating software was developed to generate standard annual, mortuary-specific and city-level reports, the first such example being the NIMSS annual report for 2002 (Matzopoulos, Seedat et al. 2003).

Butchart et al. (2001) did note the complexity of spatially mapping cases using GIS, which was attributed to the lack of consistency between formally defined suburb boundaries and those perceived by the mortuary personnel. As a result, detailed spatial analysis was discontinued after the initial pilot from 1998 to 2000, with carefully demarcated cities the preferred unit of analysis until such time as the spatial data deficiencies could be addressed. The lack of consistency between demarcated and perceived suburb boundaries has been addressed with the inclusion of a "closest police station" variable. This is a spatial category well-understood by mortuary personnel who, when collecting bodies from the scene of death, are in close contact with police officers. As officers are always assigned from the closest police station and are required to follow-up and file crime reports for all non-natural deaths within their jurisdictions, this is expected to provide a more accurate spatial allocation of cases than suburbs, the boundaries of which may be subjective. The PIMSS will revisit geospatial data analysis, as linkages between the place of residence and place of death will enable more complex analysis, utilising suburb-level descriptors from Census data. Already the data have been applied at the sub-district level within Cape Town to highlight disparities in health (Groenewald, Bradshaw et al. 2010).

3.2. Flexibility

Among the constraints to introducing mortuary-based injury mortality surveillance during the initial NIMSS pilot in the late 1990s, Butchart et al. (2001) cited difficulties in introducing the data collection form at mortuaries (ascribed to organisational rigidity), and also logistical difficulties when applying modified versions of these forms, as changeovers were not always simultaneous. Clearly, the institutionalisation of the PIMSS in the Western Cape indicates that organisational constraints have been overcome and greater flexibility is afforded through the integration of the case report form as part of the FPS' electronic interface. In addition, the case report form used for the PIMSS is the fourth version since the system's inception and reflects the first major revision. Previous revisions had included minor changes to coding (e.g. the introduction of an 'electrocution' tick box among the external causes of death) and the addition of extra variables, e.g. the introduction of 'medical treatment of injury prior to death' (see section 5.4). These revisions have not hindered analysis or the production and dissemination of routine reports.

On the positive side, Butchart et al. (2001) note the flexibility of the data analysis functionality that enabled the system to accommodate diverse, ad hoc information requests and rapid customised analyses. The seemingly simplistic tick-box coding masks a multi-dimensional cause of death coding that can be readily mapped to numerous ICD codes. At an operational level, this flexibility has been demonstrated through the surveillance system's fluctuating, but constantly expanding coverage of the national non-natural mortality caseload and its continuation through large-scale organisational restructuring at the mortuaries and to a lesser extent the managerial arrangements within the implementing agencies.

3.3. Acceptability and organisational constraints

During the pilot phase, the Departments of Health, and Safety and Security, were jointly responsible for the administration of the forensic medical examination process. Although the NIMSS was supported by top management of both departments, dual control undermined implementation and Butchart et al. (2001) noted that system acceptability varied according to whether the primary contact at individual mortuaries was a police officer or a forensic pathologist with an academic appointment. In the case of the latter there were fewer organisational constraints as the purpose of the surveillance was more compatible with the priorities of health departments.

Some police officers were concerned that the system would threaten the investigative process as sensitive information was being captured before the completion of court investigations. In addition, the organisational rules of the SAPS, which demanded that decisions be referred to higher levels of command, which had resulted in delays in implementation (Butchart, Peden et al. 2001).

It was expected that the problems of dual control would be overcome with the successful transfer of management to the Department of Health in April 2006. However, at the time of writing an unforeseen dispute had arisen between the research agency co-ordinating the system (i.e. the MRC-UNISA Crime, Violence and Injury Lead Programme) and forensic pathologists in the employ of the Department of Health relating to data ownership, the publication of research findings and authorship. Unless a formal resolution is agreed governing access to and use of the data the long-term viability of the surveillance system in its current format at a national level may be threatened. In the Western Cape institutionalisation of the system should ensure the continuation of the derivative PIMSS.

3.4. Sensitivity

A surveillance system's sensitivity is defined as its ability to correctly identify all cases in a target population. Butchart et al. (2001) described the within-system sensitivity as the number of cases logged by the surveillance system as a percentage of total cases processed by each mortuary, which during the pilot phase was measured as 95 percent. However, the system's external sensitivity was not measurable directly, as there was no reliable alternative method for identifying all non-natural deaths.

Under the Births and Deaths Registration Act (Republic of South Africa 1998) all deaths are subject to death notification and registration with the Department of Home Affairs, but not all deaths are reported, with the latest estimate suggesting that only 79 percent of female and 87 percent of male deaths were registered in 2007 (Statistics South Africa 2009). Under-reporting was biased towards rural areas that were not routinely covered by the mortuary surveillance system. Consequently comparable data disaggregated according to the areas served by the surveillance system were not available and, even if they were, they could not have been matched to the mortuary catchment areas as the location of death was based on the place of residence rather than the place of death, which is recorded in the mortuaries.

Full national coverage of mortuaries may have enabled measurement of the surveillance system's sensitivity in identifying the total number of non-natural deaths, provided that the official death registration data had been adjusted for underreporting in rural areas. However, the large percentage of ill-defined causes in the official data - three-quarters of non-natural deaths and 67 percent of deaths due to undetermined intent (Statistics South Africa 2005) - would limit the utility of the death registration data in validating the sensitivity of the surveillance system in recording specific subsets of injury such as homicides, suicides and traffic crashes, etc. Alternatively, comparison with other data sources, such as the police and road traffic agencies, that provide substantial coverage of specific subsets can demonstrate the system's external sensitivity.

As shown in section 6.1 of the results chapter the assumption of full coverage of the homicide statistics held true when the data were compared with the murders recorded in police crime statistics over the corresponding period. It was also clear that more detail was available from the mortuaries with regard to the causes and demographic factors associated with homicides. For example, in Cape Town mortuaries identified 20 percent more firearm-related deaths in children and adolescents than were included in official police crime statistics (Wigton 1999) and another study showed that nationally mortuaries were better at reporting female homicides (Mathews, Abrahams et al. 2004).

The other major fatal injury category, road traffic injuries, was less conducive to comparison due to substantial and inconsistent levels of under-reporting in the official statistics produced by the Department of Transport. For example, in 2000 a total of 5848 deaths were reported by the Department of Transport, based on cases reported by the police to the National Arrive Alive Fatal Accident Information Centre. Annual road deaths were reported to have risen to 9918 in 2002, the most recent year for which these data were available (Arrive Alive). In contrast, estimates from the National Burden of Disease Study, which projected the mortuary-derived distribution to all non-natural deaths, estimated that there were approximately 15,000 deaths in 2000 (Bradshaw, Nannan et al. 2004). The latest estimate of 14,920 deaths in 2007 in the *Global status report on road safety* (2009), which was derived from multiple data sources and expert consensus, gives credence to the mortuary-derived estimate. A recent UCT masters dissertation compared road traffic fatalities from police versus mortuary data and found that the police data under-reported traffic fatalities by almost 50 percent (Chokotho 2011).

In addition, the sensitivity of the surveillance system has been demonstrated for other fatal injury subsets. For example, Cape Town mortuaries recorded 20 percent more fatalities than were identified by the rail local rail utility (Lerer, Matzopoulos 1996). Similarly, a review of occupational deaths identified from post mortem investigations at Salt River and matched with the records of the occupational safety inspectorate showed that 28 percent had not been reported in terms of statutory regulations (Lerer, Myers

1994). Another study measured the accuracy of suicide mortality data arising from the surveillance system in Pretoria by tracking cases through several years of medico-legal investigation. The overall sensitivity of the surveillance data was found to be 88 percent (Burrows, Laflamme 2007), which is remarkably high considering the legal complexity in determining suicide as an outcome.

3.5. Positive predictive value

Positive predictive value, or the likelihood that an event recorded by the surveillance system actually occurred was only possible following the completion of court investigations. Butchart et al. (2001) resorted to measuring inter-rater agreement due to the long delays in the completion of court investigations by comparing the cause of death recorded in the surveillance system against the assessment of an independent coder for a 10 percent random sample of cases seen at the pilot mortuaries. However, Butchart et al.'s analysis did not assess positive predictive value, but rather reliability and inter-rater agreement.

Despite the absence of an objective criterion or "gold standard" from which to validate injury mortality surveillance systems, the strict legal requirement that all non-natural deaths be subject to medicolegal post-mortem examination (Republic of South Africa 1959) implies that mortuary-based surveillance data can reasonably be assumed to provide full coverage of non-natural deaths and, furthermore, that the data provide a useful benchmark with which to assess the completeness of other data sources. In this study the NIMSS homicide data were compared with published police statistics on murders in Cape Town, Durban, Johannesburg, Port Elizabeth, Pretoria[8] for the period April 2001 to March 2005 (, South African crime statistics by province: 2005). Due to the SAPS practice of recording their crime statistics according to financial years, this provided four years of data for comparison (Table VII).

Table VII. Periods corresponding with SAPS annual reporting periods (2001-2005)

Period	Dates
SAPS Year 1	1 April 2001 – 31 March 2002
SAPS Year 2	1 April 2002 – 31 March 2003
SAPS Year 3	1 April 2003 – 31 March 2004
SAPS Year 4	1 April 2004 – 31 March 2005

The police catchment areas that corresponded most closely with the mortuary catchments for each city were as follows: Cape Town included the East and West Metropole; Durban included Durban North and South for Durban; Johannesburg included North Rand and Soweto; and Port Elizabeth included Uitenhage. There was no policing area subdivision in Pretoria. Comparative results of the NIMSS versus police homicie data are summarised in section 6.1 of the Results chapter.

Previously, mortuary-based surveillance data had been used to assess underreporting for the subset of rail fatalities following the city-wide pilot implementation in Cape Town in the mid1990's. The mortuary-based data were used to assess the rail utility's level of reporting in terms of the Machinery and Occupational Safety Act of 1983 (MOSA) and Occupational Health and Safety Act of 1995 (OHSA) requirements. The results were presented according to the five main cause of death groupings, i.e. deaths due to falling from a train, being struck by a train, suicide, violence, and other causes. Where MOSA and OHSA forms could not be found among the railway records for deaths recorded as "railway deaths" at the mortuaries, the mortuary records were recorded as unmatched. For the two cases recorded by the rail utility that could not be matched with mortuary records, it was assumed that matching mortuary records had been recorded, but had been missed. Possible reasons included timing differences caused by police investigations and toxicology results that may have resulted in incorrect information being captured as to the time of death, or the mortuary record not specifying that the body had been retrieved from next to a railway line or from the rail utility's property. For example in the case of a body found next to the line with multiple injuries, Cape Metrorail might have recoded the cause of death as a pedestrian train collision, whereas an autopsy might conclude that the cause of death was an assault and that the body had been dragged to the site.

The large differences in the estimated total number of injury-related deaths in the national burden of disease study for the two major causes, i.e. homicide and road traffic fatalities (Bradshaw, Nannan et al. 2004) compared to officially reported police homicide and Department of Transport road deaths prompted the National Department of Health's Directorate of Mental Health and Substance Abuse to fund a validation study in 2002 to investigate the discrepancies between the data collection systems of various agencies collecting data on non-natural deaths. A research team comprising researchers from the MRC and UNISA compiled a technical report, which described the data collection systems schematically and identified areas of potential data loss (Burrows, Matzopoulos et al. 2004). It should be noted that the assumption that the mortuary-based surveillance can be used as a 'gold standard' is predicated on the premise that the system provides a high degree of sensitivity and positive predictive value. As the surveillance data only provide an *apparent* manner of death, it was necessary to critically examine the process by which mortuary-based data were collected alongside those of other agencies that collect information on non-natural deaths such as the Departments of Transport, Safety and Security and Home Affairs. The initial project proposal had also alluded to a subsequent quantitative phase of the study that would measure data loss (underreporting or misclassification) by tracking a sample of cases through the different agencies. This was to take place during the piloting of a revised NIMSS case report form that was to be developed in consultation with the forensic pathologists. However this phase of the study was not funded, possibly owing to discontinuity in senior management within DoH's Mental Health and Substance Abuse Directorate, which would have hindered the high-level facilitation that interdepartmental data access required.

The NIMSS homicide estimates have also been compared to police murder statistics (Altbeker 2005, Matzopoulos 2005) and, more recently, Burrows and Laflamme used the NIMSS data as the "gold standard" in their study on the accuracy of the suicide data recorded in the recorded in the criminal justice system (Burrows, Laflamme 2007). The sensitivity, specificity, and predictive values were found to be generally high for those cases that could be classified as suicide or not suicide. Similarly, in an MPH project to assess the quality of data sources on road traffic injuries in the Western Cape, Chokhotho (2011) found that the mortuaries identified nearly twice as many road deaths as data from the police and traffic authorities.

The latest case report, which was informed by the schematic depiction of the data collection systems included several innovations that were subsequently incorporated in the Western Cape PIMSS. These included separate sections for completion by different mortuary personnel, a revised cause of death category that better emulated ICD, and the inclusion of the death register serial number for linking with vital registration data.

3.6. Data quality

Questionnaires originally completed by mortuary staff during the system pilot were compared with questionnaires from a 10 percent random sample completed by trained field workers to gauge the agreement between different variables. Individual validation reports were produced for each mortuary, which highlighted problem variables (i.e. where there was a lack of consistency between the two data sets) and provided a set of recommendations for the medical examiners and mortuary personnel. Butchart et al. (2001) observed that data accuracy varied across mortuaries and for different items (Table VIII).

Table VIII. Items correctly recorded by four NIMSS mortuaries in Gauteng

Item	Diepkloof (%)	Roodepoort(%)	Germiston (%)	MEDUNSA (%)
Police no.	22	82	60	76
Investigating officer	86	88	98	40
Postmortem no.	100	100	100	100
Postmortem date	90	97	94	92
Pathologist	96	100	98	100
Date of injury	37	58	32	36
Time of injury	69	79	48	28
Date of death	90	89	98	96
Time of death	69	79	48	28
Race	98	97	98	100
Sex	100	97	97	96
Age	37	76	65	84
Province	82	82	81	76
Town	73	60	45	76
Suburb	71	44	47	76
Scene	41	32	18	60

Source: Butchart et al.(2001)

For the ‘apparent manner of death’ and the ‘circumstance of death’ Butchart et al. (2001) observed that the percentage agreement across a sample of four Gauteng mortuaries ranged between 71 percent and 82 percent. Inconsistencies often arose from assumptions made by mortuary staff on the basis of the external cause of death. For example, ‘burn’ deaths were frequently coded as ‘unintentional’ whereas they could have been intentionally inflicted. Thus the correct coding would have been ‘undetermined’, which is consistent with the premise that a higher rate of negative autopsies (i.e. those in which no obvious cause of death is apparent) originate from more experienced pathologists (Knight 1990).

Another common problem was the coding of road traffic injury deaths as ‘homicides’ due to their classification as ‘culpable homicides’ in the criminal justice system, which was easily rectified at the data cleaning stage. Accuracy may have been low for some items because the required information was unavailable at the time of the record being captured even if information became available later. This was certainly the case with blood alcohol and other toxicology results, which were usually only available some six months following the post-mortem (Butchart et al. 2001).

In recent years results were obtained directly from the state chemical laboratories in Cape Town, Johannesburg and Pretoria and matched through post-mortem numbers, which were very accurately recorded. Another problem was mortuary staff making assumptions in order to complete case report forms. This was the case with the date and time of injury, which was not routinely available, but was frequently recorded incorrectly by mortuary staff as coinciding with the date and time of death.

Validation reports were compiled at other mortuaries following the pilot study described by Butchart et al. (2001) and on average, high levels of agreement (i.e. of more than 90 percent) were obtained for the following variables: 'sex', 'age', 'race', 'date of death', 'post mortem number', 'post mortem date', 'pathologist'. As the system expanded, regional data co-ordinators were tasked with the ongoing monitoring and liaison with mortuary staff regarding issues of data quality.

3.7. Timeliness

For the pilot study Butchart et al. (2001) measured the internal timeliness according to the average time between the occurrence of death and the capture of information as as an electronic record. For all except the blood alcohol and toxicology results, data were on average captured within five weeks of the death. Quarterly reports for each mortuary were completed approximately within six weeks after data were obtained from participating facilities, cleaned and summarised according to a uniform template.

In subsequent years the data were summarised in a national annual report and in individual mortuary-specific reports that were typically published in the following year. This provided a window period for outstanding toxicology data to be processed and collated. Data processing was also expedited through the development of the automated report generating software, which was first piloted in 2002 and utilised from 2004 onwards.

3.8. Data usefulness

The numerous reports and documents arising from the surveillance data are described in the section 1.4 – Reporting and Dissemination. At the time of the pilot, Butchart et al. (2001) noted that a number of reports had been prepared in response to special requests from national and local government departments. The research findings had been used to influence policy changes and prevention activities in relation to firearm-related deaths, violence among adolescents, and child pedestrian safety, which was later confirmed by two related studies (Burrows 2001, Seedat, Nascimento 2003) (Burrows 2001, Seedat, Nascimento 2003). This pattern has continued throughout the system's development, and in addition to the standard annual reports, the system has responded to numerous requests for data and customised analyses.

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CHAPTER 4: AIMS AND OBJECTIVES

The principal aim of this thesis was to apply more complex statistical analysis and modeling techniques to the homicide data collected by South Africa's mortuary-based surveillance system and the first objective was to estimate and compare homicide incidence rates across the country's five major cities for the period 2001 to 2005.

The literature review in Chapter 2 highlighted the abnormally high levels of violence that continue to afflict South Africa and described numerous risk factors of which many feature prominently in local studies. As several key risk factors are routinely collected in mortuary-based injury mortality surveillance the second objective was to better understand the relationship between homicide and various covariates, specifically:

- To determine whether *age*, *sex*, *race*, *day of week*, *city* and *year of death* constituted independent predictors of homicide;
- To determine whether effect modification could account for the relationships between *city*, *race*, *sex* and *age*; and
- To determine whether the introduction of gun control legislation in 2004 affected a decrease in firearm homicide.

The literature review allowed conjecture regarding certain *a priori* hypotheses to explain these relationships. These hypotheses together with brief explanatory information leading to their formation appear numbered below.

1. ***age*, *sex*, *race*, *day of week*, *city* and *year of death* were expected to constitute independent predictors of homicide.**
    1.1. **Homicide rates by *age* were expected to peak among young adults.**
    1.2. **Males were predicted to be considerably more at risk than females.**

1.3. **As regards *race* it was hypothesised that Africans would be at greater risk than any other group, followed by Coloureds then Asians and Whites.**

This is consistent with *race* being used as a proxy for socio-economic status, and the deeper hypothesis which could not be tested because of limited available data for SES covariates that more marginalised groups are at greater risk of homicide and violence. The hypothesis contradicts the assertion by Seedat, Niekerk, Jewkes, Suffla, and Ratele (2009), that South Africa's highest homicide rates are among Coloureds.

1.4. **Homicides were expected to be more frequent on weekends.**

This is presumed to reflect increased social interaction and alcohol and other drug use;

1.5. **Cape Town, Port Elizabeth and Durban were hypothesised to have higher homicide rates than Johannesburg and Pretoria**.

This is consistent with the city homicide rates presented in the annual NIMSS reports in 2003, 2004 and 2005, but contrary to the popular perception that homicide is more frequent in Gauteng, as reported in the 2007 Victim Survey prepared for the Institute for Security Studies by Markinor (Institute for Security Studies 2008) in which Gauteng respondents were more concerned about personal safety during daylight hours and after dark than respondents in any other province.

1.6. **The *year of death* was expected to be an independent predictor of the homicide rate.**

See also hypothesis 3.

2. **Effect measure modification was hypothesized involving the relationships between *city*, *race*, *sex* and *age***, specifically:

2.1. that **homicide patterns by *race* differ from city-to-city, with a higher homicide risk among whites residing in Johannesburg than in Cape Town.**

This hypothesis arose from the common perception of a crime-ridden Johannesburg with whites being at greater risk of homicide. An indication of the perception of relative safety in Cape Town among whites is that Cape Town had the fastest growing white population during the study period.

2.2. that **homicide patterns by *age* differ by *race*, with**

2.2.1 **disproportionately higher homicide risk among young Africans** due to their lower socio-economic status, higher levels of unemployment and lack of access to recreational opportunities driving the higher overall homicide rate in that race group; and

2.2.2 **disproportionately higher homicide risk among elderly whites.**

The basis for this is that elderly whites are more vulnerable not only physically, but also economically and socially post-retirement and have reduced security;

2.3. that ***race* modifies the effect of *sex* on homicide**, **and that Coloured women were at significantly higher risk of homicide than women in other race groups.**

This was reported in a national study of female homicide using 1999 data (Mathews, Abrahams et al. 2004) .

3. It was hypothesised there would be a significant decrease in firearm homicide specifically, coinciding with the period preceding the introduction of gun control legislation in 2004 during which time there was stricter licensing and reduced circulation of hand-guns. The corresponding non-firearm homicide rate was expected to remain more constant.

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CHAPTER 5: METHODS

The methodological issues pertaining to this thesis are discussed according to the following schema: 1) study design, 2) data sources and ownership, 3) representativeness, 4) case report form, 5) key variables, 6) data capture and cleaning, 7) data quality, 8) data management, 9) data analysis, 10) estimation, 11) validating other information systems and 12) ethics and confidentiality.

The aspects relevant to the forthcoming results (Chapter 6) are foregrounded, but there are also several methodological issues of interest that arose during the ancillary studies that preceded this thesis. These are included within each sub-section in the following sequence: i) generic issues pertaining to injury mortality surveillance in South Africa, ii) the Cape Town city-wide pilot (1994-1995), iii) the railway injury study (1992-1996), iv) the National Injury Mortality Surveillance System (NIMSS) pilot (1998-2000), v) the NIMSS city-level surveillance (2001-2005), and vi) the Western Cape Provincial Injury Mortality Surveillance System (2007 onwards)

5.1. Study design

The current study comprised a retrospective population based study of homicide over a five-year period from 2001 to 2005 across five South African cities, namely Cape Town, Durban, Johannesburg, Port Elizabeth and Pretoria. The study population was defined as the residents of these five cities during the time period.

5.2. Data sources and data ownership

The data included in the analysis in the Results (chapter 6) was aquired from the National Injury Mortality Surveillance System (NIMSS) city-level surveillance between 2001 and 2005 as described in section 1.3. The information gathered by this surveillance system was routinely available from the death registers, autopsy reports and ancillary police and laboratory documentation from the mortuaries, or forensic pathology laboratories as they are now known. The availability of this information was due to the provisions of the Inquests Act, which required that all deaths in South Africa due to causes other than natural causes (i.e. injury deaths) be subject to post-mortem examination by a district surgeon, forensic pathologist or medical practitioner (Republic of South Africa 1959). It was also common practice to admit to the mortuaries those in whom it was impossible to determine the cause of death. Deaths while under the influence of local or general anaesthetic or where anaesthetic could have been a contributory factor were also regarded as due to non-natural causes (Republic of South Africa 1973).

The mortuaries themselves varied considerably in their capacity and coverage. Large mortuaries in major urban centres, such as those where the first data was collected in the Cape Town city-wide pilot from 1994 to 1996 process in excess of 2000 cases annually, many of these from outside demarcated city boundaries. These mortuaries are managed by dedicated personnel, and frequently include affiliates at forensic medicine departments on university medical campuses. In contrast, mortuaries in rural areas are often served by district surgeons and many only process a few dozen cases annually on an ad hoc basis.

In the case of the railway injury research conducted by the MRC for Cape Metrorail, which also included rail fatalities specifically from from Stellenbosch and Paarl mortuaries for the period of April 1992 to October 1994, the data were complemented by several other sources. Incident report forms for all incidents identified by rail utility employees that resulted in non-fatal injury or death (Lerer, Matzopoulos 1996). These forms were collected in compliance with the Machinery and Occupational Safety Act of 1983 (MOSA) that was superseded by the Occupational Health and Safety Act of 1995 (OHSA). More detailed information on the causes of injury was available when these cases could be matched with cases presenting to mortuaries. Commuter population data for the corresponding periods were obtained from intermittent travel surveys that were conducted by Cape Metrorail during the 1990s in order to calculate injury risks. In addition, historical data were obtained to juxtapose the injury and safety problems at the end of the 19th century with those revealed through the analysis of more recent mortuary, hospital and occupational health data. These historical data were drawn from archival material in the form of reports from the General Manager of the Railways and newspaper articles from 1890 to 1910, which were obtained from the Government Publications Department of the University of Cape Town Library and the South African Railway History Society (Matzopoulos, Lerer 1998).

The replication of the Cape Town all cause injury surveillance project as a national sentinel surveillance pilot in the late 1990s included eighteen mortuaries selected across eight cities. It was assumed that these facilities would be more likely to have the necessary equipment, resources and personnel for successful implementation and, as they also had larger caseloads, a substantial proportion of the national fatal injury caseload would be captured from relatively few facilities. The estimated target caseload of 38,000 cases per annum would, at the time, have represented approimately half of the national caseload (*Report on the investigation into the transfer of medicolegal mortuaries from the South African Police Service to provincial Departments of Health.* 2000). However, implementation was not as straightforward in other centres as described in the initial evaluation of the pilot system (Butchart, Peden et al. 2001). By June 1999, data had been obtained for 10 of the 18 mortuaries (Table IX). In Gauteng, two of the proposed pilot mortuaries, Hillbrow and Springs, were closed in the early stages of the proposed implementation. Data collection was maintained at Diepkloof for 7 months until labour disputes over broader issues also affected data collection. Pretoria Mortuary lacked the requisite computer resources to run the NIMSS data collection software,[9] and in Bloemfontein, Pinetown, Phoenix and New Brighton this problem was compounded by the lack of human resources to complete the forms and capture the data.[10] Nevertheless, the 6,202 cases recorded by end-June 1999 represented approximately 20 percent of the 30,000 non-natural deaths that occurred in South Africa during the six month period (Butchart, Peden et al. 2001), despite the ten facilities comprising only 4 percent of the

[9] This was later addressed through computers donated by the Department of Health
[10] This was partially resolved in later years with the retrospective collection of the data by dedicated fieldworkers in the two Durban mortuaries (Pinetown and Phoenix) and at New Brighton Mortuary.

246 sites at which post mortem investigations are conducted in South Africa (Nel, Mafungo et al. 1997).

Table IX. Mortuaries included in the NIMSS and number of cases seen in 6 months

Province	Mortuaries						
Gauteng	MEDUNSA	Roodepoort	Germiston	Diepkloof	Springs	Hillbrow	Pretoria
	257	653	1,109	NCD	Closed	Closed	NCD
Western Cape	Salt River	Tygerberg					
	1,179	994					
KwaZulu-Natal	Gale St	Pinetown	Phoenix				
	1,237	NCD	NCD				
Northern Cape	Kimberley						
	122						
Eastern Cape	New Brighton	Woodbrook	Gelvandale	Mount Rd			
	NCD	396	89	166			
Free State	Bloemfontein						
	NCD						

NCD = not collecting data at end June 1999

Source: Butchart, Peden et al. (2001)

There were also tensions resulting from the uncertainty regarding mortuary line management functions and possibly a lack of clarity around data ownership. When the first mortuary-based injury surveillance system was piloted in Cape Town in the early 1990s, mortuaries were under police management, an anomaly of the apartheid state. Although their transfer from the police to the health department was first announced in 1997, they were only vested under the authority of provincial departments of health nearly a decade later from April 2006 (, Statement by Dr Manto Tshabalala-Msimang, Minister of Health, on the official transfer of government forensic mortuaries from the SAPS to the Department of Health 2006). This protracted process presented researchers with both a challenge and an opportunity. On the one hand it was sometimes difficult to obtain permission to obtain the statistics from police officers in charge of the mortuaries, hence the slow uptake of data collection in certain mortuaries, such as Hillbrow Mortuary in Johannesburg (Butchart, Peden et al. 2001). In several mortuaries, despite endorsement by medical examiners, police personnel could not be convinced to participate and assist in entering and collating data. In certain instances it was necessary to appoint fieldworkers to collect data retrospectively (e.g.at New Brighton Mortuary in Port Elizabeth and Chatsworth Mortuary in Durban) in order to maintain full city-wide coverage.

On the other hand, it did provide researchers with a window of opportunity in which they were able to devise and implement prevention-focused surveillance systems with limited bureaucratic interference. Following the transfer of control of mortuaries from the police to health, access and utilisation of the data has become somewhat more restricted, with the national and provincial Health Departments frequently asserting their rights as ultimate custodians and owners of the data and requiring that the utiliation of the data be fully accountable to provincial health research ethics oversight and alignment with provincial prevention priorities. Subsequently, full coverage of the five cities described in this analysis has not been maintained post 2005 and, since 2007, only Johannesburg and Cape Town retain full coverage.

Although the NIMSS, now under management by the Medical Research Council's Crime Violence and Injury Lead Programme, has at times increased the number of mortuaries included in the system and also the number of cases, coverage has been erratic in that participating facilities have changed year-on-year. However, in the Western Cape a Provincial Injury Mortality Surveillance System was established as a partnership between research agencies with the Provincial Department of Health. This system came into being shortly after mortuaries were transferred from the control of the police to the Department of Health's Forensic Pathology Service (FPS) and has provided full coverage of non-natural deaths from the province's eighteen mortuaries from 2007. Data were initially collected manually according to a revised data collection form developed in consultation with the FPS whereafter the form was integrated within the provincial FPS information system during the course of 2007 and 2008.

5.3. Representativeness

Full coverage of non-natural deaths was assumed due to the provisions of the Inquests Act (1959) and hence full coverage of all injuries. Among the major South African cities where injury mortality surveillance was established data was first available for Cape Town from the two mortuaries at Salt River and Tygerberg from the city-wide pilot from 1994 to 1996, and as part of the NIMSS pilot from 1999 to 2000. Full coverage of Cape Town was eventually attained in 2001 with the inclusion of Stellenbosch mortuary, which serviced Cape Town's Somerset West/Helderberg sub-district as well as cases spilling-over into the Stellenbosch catchment area from the ever-expanding settlements on the Cape Flats. Full coverage of Port Elizabeth and Pretoria was attained in 2000 and in Durban, East London and Johannesburg from 2001 (Table X). As indicated by the shaded boxes in Table X, this coverage was maintained in five of the cities from 2001 to 2005 (i.e. in Cape Town, Durban, Johannesburg, Port Elizabeth and Pretoria), but not in East London. Consequently it is the data from these five cities, and from 15 different mortuaries, for the period 2001 to 2005 that were utilised for further analysis in this thesis. These data were considered to be representative of the all the injury deaths occurring in the five cities for the period in question.

Table X. Non-natural mortality caseloads from mortuaries in major cities included in mortuary-based surveillance systems, 1994-2005

City	Number of cases / year											
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cape Town	3,907	4,176	4,588	*	*	4,498	4,649	5,175	5,217	4,639	4,409	4,716
Salt River	2,511	2,707	2,924	*	*	2,483	2,498	2,642	2,618	2,403	2,178	2,302
Tygerberg	1,396	1,469	1,664	*	*	2,015	2,151	2,089	2,178	1,974	1,896	2,041
Stellenbosch#	*	*	*	*	*	*	*	444	421	262	335	373
Durban	*	*	*	*	*	2,621	2,365	4,518	4,725	4,645	4,473	4,379
Gale St	*	*	*	*	*	2,621	2,365	2,400	2,428	2,399	2,241	2,234
Pinetown	*	*	*	*	*	*	*	845	927	840	886	864
Phoenix	*	*	*	*	*	*	*	1,273	1,370	1,406	1,346	1,281
Johannesburg	*	*	*	*	*	4,763	5,454	8,331	8,149	7,978	7,375	7,812
Germiston	*	*	*	*	*	3,375	2,616	2,404	2,534	2,495	2,387	2,721
Roodepoort	*	*	*	*	*	1,388	1,145	1,363	1,198	1,340	1,216	1,196
Johannesburg	*	*	*	*	*	*	*	2,744	2,775	2,480	2,271	2,286
Diepkloof	*	*	*	*	*	*	1,693	1,820	1,642	1,663	1,501	1,609
Port Elizabeth	*	*	*	*	*	980	1,769	1,721	1,639	1,610	1,657	1,780
Mount Road	*	*	*	*	*	402	383	320	299	330	358	428
Gelvandale	*	*	*	*	*	578	724	630	600	552	549	609
New Brighton	*	*	*	*	*	*	662	771	740	728	750	743
Pretoria	*	*	*	*	*	544	2,220	2,579	2,509	2,475	2,480	2,393
MEDUNSA	*	*	*	*	*	544	483	495	589	634	602	572
Pretoria	*	*	*	*	*	*	1,737	2,084	1,920	1,841	1,878	1,821
East London	*	*	*	*	*	991	784	1,435	1,473	1,406	1,238	846
Woodbrook	*	*	*	*	*	991	784	952	1,008	985	931	846
Mdanantsane	*	*	*	*	*	*	*	483	465	421	307	*

Non-natural deaths occurring within Cape Town's eastern suburbs along the False Bay coast were included within the Stellenbosch Mortuary catchment area.

Similarly, the cases included in the Cape Town pilot were seen as being representative of the city of Cape Town aside, that is, from the Helderberg Health District, which was serviced by Stellenbosch Mortuary. However the railway injury data collected between April 1992 and October 1994 corresponded with the entire rail system under management by Cape Metrorail. This included 101 stations in three main sectors, the *Khayelitsha*, *Southern*, and *Northern* sectors (see Figure 3), of which large tracts of the latter were in the catchment areas of the Stellenbosch and Paarl mortuaries. The surveillance system was thus representative of the catchment area of the rail system itself, rather than the city.

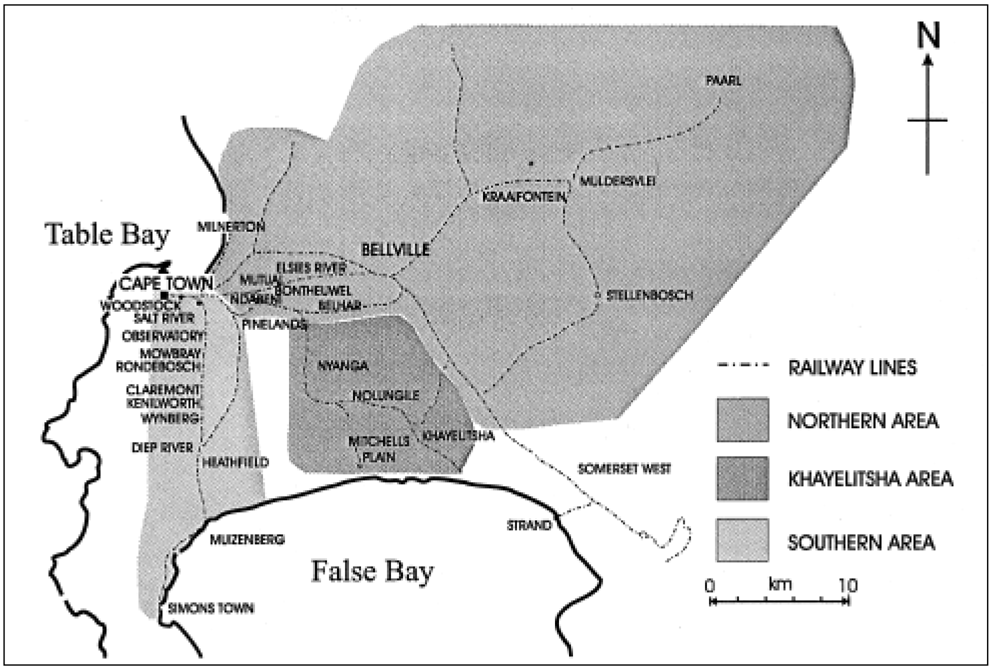

Figure 3. Map of the Cape Town metropolitan railway system.

Source: Matzopoulos and Lerer (1998)

Ensuring full coverage within a defined geographic boundary was an important feature that ensured both representivity and also the calculation of mortality risk against a defined population. When the national sentinal system was piloted in the late 1990s the data were of limited and uneven representativeness. The exceptions were Cape Town and Kimberley, where the catchment areas of the mortuaries already included the entire city limits. In Port Elizabeth only two out of three mortuaries participated, in Johannesburg only two out of four, in East London one out of two and one out of three in both Pretoria and Durban.

Thereafter there was a deliberate attempt to consolidate the surveillance system in urban areas during the period of expanding coverage from 2000 to 2005, and to ensure full coverage of those cities where there pilot sites had been established. Sustainability due to better resourcing as described in section 5.2 was one driver, but so too was the perception that compliance with the Inquests Act might be stricter in urban areas as law enforcement and social services were better resourced and it would be more difficult to dispose of bodies without alerting local authorities. As the data could reliably be perceived as representative, city-wide surveillance was viewed as an important mechanism with which to catalyse injury prevention activities at the city level (Matzopoulos, Seedat 2005). One limitation of this approach was the minimal attention accorded rural surveillance and the NIMSS data were rightly considered more representative of the urban rather than the rural injury profile. Even so, the NIMSS data were used to inform the injury profile of the first National Burden of Disease study (Bradshaw, Groenewald et al. 2003) after validating the NIMSS-based profile and the age and sex distributions for the major causes of injury-related deaths (homicide, road traffic collisions, suicide, fires, and drowning) against other sources. These included the 1988/1989 mortality data from Statistics South Africa, the 1994 Cape Town city-wide pilot study (Lerer, Matzopoulos et al. 1995), the re-analysed 1990 Cape Metropole Study (Norman 2002) and data from two demographic surveillance sites in rural settings, i.e. Agincourt and Hlabisa. In summary, it was found that while injury-related mortality rates in rural areas were lower, the distribution of the causes of injuries were similar (Bradshaw, Groenewald et al. 2003).

The urban bias has been addressed more recently in some provinces, such as in the Western Cape, where the PIMSS provides coverage of all forensic pathology laboratories in the Western Cape Province, and in Mpumalanga, where fieldwork teams from the MRC CVI's collaborating centre at the UNISA Institute for Social Health Sciences (ISHS) collected complete provincial data for 2008 and 2009. In addition, an Injury Mortality Study currently underway as part of the second National Burden of Disease study will collect a representative sample of injury mortality data from across South Africa and provide a definitive source from which to compare the urban-rural and different provincial injury profiles and their demographic distributions.

5.4. Case report form

The data utilised in the multivariable analysis were collected using either the data collection form from the sentinal surveillance system pilot, or a new iteration of this form with minor modifications. Protoypes of the form used in the pilot had been applied in earlier studies of fatal injuries that confirmed the feasibility of implementing it on a wider basis (Peden, Meumann et al. 1998, Lerer, Matzopoulos et al. 1997). The pilot form included 23 information items, which were all pre-coded, except for the geographical information and the "context of attack" fields. Case identifiers comprised four items: (1) the mortuary name, (2) the police crime analysis system (CAS) number, (3) the post-mortem (or mortuary death register) number, and (4) the date of the post mortem. Personnel identifiers comprised two items: (5) the name of the mortuary attendant and (6) the name of the medical examiner. Nine items recorded additional details of the fatal injury event including (7) the date and time of injury and (8) the date and time of death; the demographic details of the deceased, i.e. (9) race, (10) sex and (11) age; the geographic location according to the (12) province, (13) town and (14) suburb of injury; and (15) the scene of injury. Two items recorded the cause of death, i.e. (16) the primary medical cause (or circumstance) of death and (17) the apparent manner of death (i.e. unintentional/accident, homicide, suicide, natural or undetermined and was determined by the medical examiner. Three items recorded the presence of (18) blood alcohol, (19) eye fluid alcohol or (20) other toxins in the deceased, to be obtained from the state chemical laboratories.

The first seventeen items were available from the post-mortem procedure, and items 18-20 were obtained from the state chemical laboratories. The last three items made provision for a more detailed classification of injuries due to intentional violence, adapted from the 1998 ICECI draft module, i.e. (21) the type of violence, (22) the victim-perpetrator relationship, and (23) the precipitating circumstances of the violent attack. This information would typically be available following inquest court investigations. The form itself was self-carbonating to protect against data loss, with one copy being retained at the mortuary for data capture and the other included in the mortuary folder. It was also envisaged that the second copy of the form would accompany the mortuary documentation as part of the case docket for court procedures and that this would enable the subsequent collection of the three outstanding data items (items 21-23). However, the court information was not available on completion of the pilot due to procedural delays and the complexity of the criminal justice system, with cases dispersed between numerous criminal record centres and inquests courts. Researchers would have needed to have actively retrieved records from each facility, a process compounded by poor data linkages and so these data were never collected. Printing costs for the original case report form were borne by the Department of Health's Directorate of Mental Health and Substance Abuse.

The revised form, which replaced the original version after stocks were depleted, contained several minor adaptations on the advice of the participating forensic pathologists (Appendix I). First the 'mortuary attendant' field (item 5 in the pilot) was replaced with the 'officer collecting the body', as very often the name of the medical examiner's assistant was recorded, which had limited utility for follow-up in the case of missing information. Second, 'informal settlement' was included as an additional 'scene of injury' field (item 15). Third, the 'primary medical cause of death' (item 16) was renamed the 'external cause / circumstance of injury' in order to denote the underlying cause. Fourth, the external cause of death categorisation was revised. This included the provision of separate options for deaths resulting from electrocution and lightning strikes, as well as the separation of deaths due to poisoning into ingestion and gassing sub-types. Finally, two additional fields were added: 'medical treatment of injury prior to death', which recorded whether the patient received emergency care at the scene or hospital treatment; and 'samples taken', which specified the nature of the samples sent to the state chemical laboratories, i.e. whether blood, tissue or other fluids. Both these fields were intended to highlight and enable linkages with records from other data sources, such as health facilities, emergency medical services and laboratories. The cost of printing this form, which was also self-carbonating, was borne by the MRC.

5.5. Key variables

Based on the review of risk factors for violence (Section 2.2) and the exploratory analysis (section 6.2) which assessed the suitability and completeness of available data, the following variables were utilised in the multivariable analysis (sections 6.3 and 6.4):

Dependent variables: Mortality counts for *homicide*, *firearm homicide* and *non-firearm homicide*; and

Independent variables: *age*, *sex*, *race*, *day of week*, *city*, *year of death* and *population*, as described in Table XI.

Table XI. Data key for variables included in the multivariable modelling

Variables	Description
Dependent	
hom	Age specific *homicide* count
homfa	Age specific *firearm homicide* count
homnonfa	Age specific *non-firearm homicide* count
mhom	Age specific *homicide* count with missing age imputed
mhomfa	Age specific *firearm homicide* count with missing age imputed
mhomnonfa	Age specific *non-firearm homicide* count with missing age imputed
Independent	
age	Age of the deceased in 5-year age categories - 1: 0-4 years; 2: 5-9; 3: 10-14; 4: 15-19; … ; 17: 80-84; 18: 85+)
sex	Sex of the deceased - 1: female; 2: male
race	Race of the deceased – 1: African; 2: Asian; 3: Coloured; 4: White
day of week	Day of week that the deceased died – 1: Sunday; 2: Monday; 3: Tuesday; 4: Wednesday; 5: Thursday; 6: Friday; 7: Saturday
year of death	Year of death that the deceased died - 1: 2001; 2: 2002; 3: 2003; 4: 2004; 5: 2005
city	City of death: 1: Cape Town; 2: Durban; 3: Johannesburg; 4: Port Elizabeth; 5: Pretoria
population	Age specific population in 5-year age categories

These variables were devised from the following more extensive list of standard information items that were typically available from the post-mortem investigation process. The source of these information items and noteworthy characteristics were as follows:

Case identifiers: While not used for analysis, the *post mortem number* along with the *mortuary name* and the *post mortem date* (specifically the year) were available for every record and, in combination, provided each case with a unique set of identifying variables.

Age: Ages of the deceased were ideally obtained during the identification process when the deceased's next of kin and/or identity document were available. Alternatively the ages of the deceased were extracted from the death registers of the mortuaries based on the expert opinion of the medical practitioner conducting the post-mortem investigation.

Sex: The sex of the deceased was usually available from the medicolegal documentation except in certain rare cases, such as when a post mortem investigation was conducted on the skeletal remains of a person long deceased. The term "sex" was preferred to "gender" as it described distinctive biological or anatomical features related to being male or female. The term gender comprises different occupational, social and psychological attributes, which frequently depend on societal norms and consequently are not comparative across different settings and disciplines.

Race: The "race" of the deceased was recorded according to the apartheid "population group" classifications, which includes the terms 'African', 'Coloured', 'Asian' and 'White'. This information has not been available in official death statistics since the repeal of the Population Registration Act and changes in the Births and Deaths Registration Act, but was still recorded in the 2001 Census.

Although the racialisation of the South African population was a social construction that served a particular political purposes, the use of the associated terms in this thesis does not imply any acceptance of the racist assumptions that underpin them, i.e. that there are any inherent biological differences between the “races”. Rather, in the absence of alternative measures of socio-economic status, “race” in the South African context provides a gross proxy measure to reflect the differential manner in which apartheid affected, and continues to affect, the lives and health of South Africans.

However, it should be noted that in South Africa *race* and *socio-economic status* may well be conflated, but *race* might conceivably also mask a range of invidious psychological and social effects on individuals, families and communities that account for the differences in homicide rates. Until reliable data on both SES and race are available, it will not be possible to separate these effects. This may be possible in future in the Western Cape, where the latest iteration of the mortality surveillance system enables the linking of the mortuary-basedsurveillance data with vital registration. This may provide a solution to the use of “race” as a proxy for socio-economic status, as vital registration provides information about the place of residence of the deceased (rather than the place of death) and hence a more nuanced understanding of the “living-circumstances” of the deceased.

Cause of death: The Regulations on the Registration of Births and Deaths stipulated that the cause of death be classified as “natural causes” or, in the case of a death due to other than natural causes the cause of death be classified as “unnatural causes” or “under investigation" as the case may be (Republic of South Africa 1998). For prevention-oriented injury surveillance there were two additional cause of death criteria of interest, i.e. the manner and the external cause of death. These two criteria were compatible with international nosology including the 9th Revision of the International Classification of Diseases (World Health Organisation 1979), which was still in use internationally when the system was first piloted, the 10th Revision (World Health Organisation 2007), which is currently in use, and the International Classification of External Causes of Injury (World Health Organisation Working Group for Injury Surveillance Methodology Development 1998).

The ***manner of death*** described the intention of the deceased and other actors prior to the injury that resulted in death, and was typically ascribed to four categories: (1) homicide (a fatal injury as a result of intentional interpersonal violence), (2) suicide (as a result of an intentional self-inflicted violent act), (3) an unintentional injury death (i.e. an "accidental" death), or (4) an undetermined death, where the medical examiner was unable to determine whether the manner of death was due to homicide, suicide, transport or other unintentional injuries, or due to natural causes. As the official manner of death is only legally finalised following a full court investigation, the manner of death attributed by the medical practitioner following the post mortem investigation was typically described as the "apparent manner of death".

The ***external cause of death*** referred to the circumstances that preceded the fatal injury event. For homicide this might have included e.g. a gunshot, or an assault with a blunt instrument, whereas for an unintentional injury death common examples included motor vehicle-pedestrian collisions, falls or fires.

In the Cape Town railway injury surveillance the *manner of death*, i.e. whether intentionally or unintentionally inflicted, was often undetermined among mortuary records, and so the MOSA and OHSA documentation was instructive in ascertaining the *manner of death* and refining the *external cause of death.* Twenty-one railway-specific causes of injury and death were identified, which were categorised into five main groupings: falls-from-train (or train injuries), struck-by-train (line injuries), suicidal acts, violence, and other. The first two categories referred to unintentional injuries, with falls-from-train comprising cases in which commuters fell from the train, were jammed in the doors, or caught between the train and the platform. These were all injuries that afflicted passengers exclusively. The 'struck-by-train' category referred to pedestrian injuries. These could comprise either commuters or other people who were exposed to the railway system and who were run over by trains while crossing the lines at stations, or when using railway lines as an access route or walkway.

Suicidal acts consisted of suspected suicides, either completed or attempted, as identified by railway personnel and the police. Violence included passengers thrown from trains, and sharp or blunt force or firearm assaults while on the train or while the train was at a station. Other causes of railway injury included electrocution and unknown causes of death due to intentional injuries, unintentional injuries, or suicidal acts; and accidental deaths not related to the operation of trains that occurred on railway property.

Alcohol: Blood was analysed for alcohol concentration, using standard gas chromatography, at the State Chemical Laboratory and results were returned to individual mortuaries, where they were attached to post-mortem reports. Most fatalities were tested, with the exception of minors younger than 18 years and deaths due to the late effects of the injury (more than six hours later), as alcohol tests would not have reflected the degree of intoxication at the time of injury.

Date and time of death and injury event: The date and time of death was usually available in the post-mortem report, or the mortuary register or, failing that, from the accompanying police report and/or hospital records. The data and time of the injury event was usually less well recorded and there was a tendency to record the date and time of death as the date and time of injury. Where these data were available, they were typically found in the police reports and/or hospital records. For railway injuries the most reliable time of injury was available from the MOSA and OHSA incident reports obtained from the rail utility. As date and time of injury were poorly recorded further refinement of date variables was restricted to the date and time of death. This included the separation into the year of death and the day of week.

Place / location of death: Province and town and sometimes also the suburb of where the injury event took place was available from the police documentation or hospital records include in the post-mortem folder. In the Cape Town pilot the place of death was recorded according to one of 57 suburbs. Each suburb was assigned to five of the six Cape Metropolitan Substructures at the time: Central, Eastern, Northern, Southern and Tygerberg. The Helderberg Substructure was excluded as it was not part of the two Cape Town mortuaries' catchment area. MOSA and OHSA incident reports obtained from the rail utility specified the location of the incidents according to the stations at which, or between which, the incidents occurred, and consequently the railway line and service sector as described in 5.3 in this chapter. As mortuaries in major urban centres typically process overflows from surrounding towns and urban areas, it was necessary to exclude cases that originated from outside city boundaries for the city surveillance. This is described in more detail under *Data management* (section 5.10 in this chapter).

Population estimates for Cape Town, Durban, Johannesburg, Port Elizabeth and Pretoria as denoted by the South African Municipal Demarcation Board were obtained from the 2001 Census community profile data sets by age, sex and race, in order to calculate mortality rates (Demarcation Board of South Africa 2006). Exponential population growth rates between 2001 and 2004 were derived from the Actuarial Society of South Africa (ASSA) demographic and AIDS model for 2003 for four provinces: Kwa-Zulu Natal, Gauteng, the Eastern Cape and the Western Cape. The KwaZulu Natal provincial growth rates were applied to Durban, the Western Cape rates to Cape Town, the Eastern Cape rates to Port Elizabeth and the Gauteng provincial growth rates to Johannesburg and Pretoria. The 2001 populations were not adjusted for any under or over counts. Although Dorrington (2005) provides an improved population estimate for Cape Town that adjusts for the deficiencies of the 2001 census, these were not applied, as similarly corrected estimates were not available for the other cities.

5.6. Data capture

Mortuary administrative personnel at 11 of the 15 mortuaries, either within the police or department of health employ, collected and captured the data included in the analysis, section 4. There were exceptions at four mortuaries (Gelvandale, New Brighton, Pinetown, Stellenbosch), where dedicated fieldworkers were appointed to extract and collect the data on the case report forms. Generally, it was expected that larger urban mortuaries that were well-resourced in terms of personnel and computer equipment would co-ordinate their own data capture, both in terms of manually recording the information on the data collection form and then entering the data into a computerised databases. Among less-resourced mortuaries, or in cases where mortuaries were unable or unwilling to accede to the system's data capture requirements, two alternative methods were applied. Mortuaries were first encouraged to record the data on the data collection forms that would then collected and collated by a regional co-ordinator, either in the employ of the research agency or the provincial department of health. Alternatively, dedicated fieldworkers were assigned to visit the mortuaries and complete the case report forms retrospectively from the post-mortem documentation. This was an expensive option that was only applied in cases where the absence of a particular mortuary's data might compromise full coverage of a key geographical area such as a city.

Transcription of data from the manual case report forms into a computerised database was undertaken centrally either at one of the Medical Research Council offices in Cape Town (cases from Western, Eastern and Northern Cape Provinces) or Durban (Kwa-Zulu Natal cases), or at their partner organisation, the UNISA ISHS, in Johannesburg (cases from Gauteng and Mpumalanga mortuaries).

5.7. Data quality

For the data utilised in the analysis in section 4 the accuracy of the apparent manner and external cause of death provided by the surveillance data was assumed. The misclassification of non-natural deaths as being due to natural causes is unusual, as non-natural deaths have legal and financial implications and medical practitioners would be cognisant of the medicolegal implications of these cases not being referred to the relevant authorities (Lerer, Matzopoulos et al. 1997). Several studies have demonstrated the comprehensiveness of the medicolegal process in respect of occupational injuries (Schierhout, Midgley et al. 1997, Lerer, Myers 1994), child drowning and female homicides (Mathews, Abrahams et al. 2004), although it is conceivable that a few deaths due to the late effects of injury may be certified as being due to natural causes, and therefore bypass the mortuaries.

The participation of a forensic pathologist in the city-level surveillance pilot and the railway injury surveillance system in Cape Town in the mid-1990s improved the assignment of the external cause and apparent manner of death. For the railway injury deaths, the accuracy of the post mortem investigation was reliant on the history provided in rail utility and police reports, as no specific autopsy features distinguished between different types of railway-related injury. This information was in turn reliant on the interpretation of the event by the observer and recorder, who in most cases would not have received any formal medico-legal training and might also be ill-equipped to distinguish between different aspects of intentionality (Lerer, Matzopoulos 1996, Matzopoulos, Peden et al. 2006). These problems would have been compounded among unobserved cases, which was one of the reasons for the restriction of the case-control study of alcohol relatedness of railway deaths being restricted to daylight hours (Matzopoulos, Peden et al. 2006). For example, it was conceivable that some suicides would have been included among pedestrian deaths and vice versa. Similarly, the extensive disruption of the body provided an opportunity for the concealment of homicides and it was conceivable that some bodies were deliberately placed on the railway tracks following homicides at other sites (Lerer, Matzopoulos 1996).

As there was no forensic pathologist assigned to the subsequent expanded surveillance systems between 1999 and 2005, researchers based in Cape Town, Durban and Johannesburg checked the data for completeness of key variables (external cause and apparent manner of death) and coherence. The researchers followed-up to retrieve and correct important missing or anomalous data with individual mortuaries where necessary. Ongoing training and liaison between the researchers and the mortuary-based collaborators also ensured a more personal and immediate interface that had the effect of gradually improving data quality.

Again, this has been addressed in the Western Cape with the integration of the PIMSS within the FPS Information System, particularly after the February 2009 system enhancements, when the following variables become mandatory: (1) the closest police station, (2) the mortuary name, (3) the province of injury, (4) the date of death, (5) the post-mortem (or death register) number, (6) the death certificate (or BI1663) number, (7) the age of the deceased, (8) the race of the deceased, (9) the sex of the deceased, (10) the cause of death, (11) the circumstance (or external cause) of injury, and (12) the apparent manner of death. In addition, date formats were to be standardised and consistent throughout the system, the "time of injury" and "time of death" fields were to be rounded off to the nearest hour and the age in years and age in months were to be recorded in separate fields.

Queries relating to key variables such as the external cause and apparent manner of death were sent to the Director of the FPS, who elicited corrections from the facility managers and, where appropriate, the forensic pathologists. It was also resolved that ongoing training of the users of the data capture system, i.e. the FPS personnel at each mortuary, would enhance their understanding of how the data was being used and would underscore the need for improved completeness and accuracy.

5.8. Data cleaning

This data cleaning was undertaken at one of the three research office sites: i.e. the Medical Research Council offices in Cape Town and Durban and the UNISA ISHS in Johannesburg. Key variables, such as individual identifiers, demographic information and especially the external cause and apparent manner of death, were checked for completeness, as well as internal congruence and consistency. For example, transport injuries were recoded as unintentional injury deaths as opposed to "homicides", which was a common practice arising from the legal definition of some of these cases as "culpable homicides". A data cleaning manual was compiled to ensure consistency across the three data cleaning sites and to reduce the workload on the Cape Town-based researchers who had to check and clean the data before they were combined into a single data set. The data cleaning manual provides a detailed account of the many types of common errors and inconsistencies that occurred in the NIMSS between 1999 and 2006 and how they were corrected. Once the data were finalised, they were uploaded to a secure server running SQL server relational database software (Microsoft Corporation 2003) to enable regional and national analysis and to provide an interface with the report generating software described in section 1.3 in Chapter 1.

Previously the data cleaning processes were considerably less-structured than those employed by the NIMSS between 2001 and 2005. However, one clear benefit during the Cape Town pilot was that as the project had been initiated at the Forensic Medicine Department at UCT, there was a forensic pathologist available to re-examine the post-mortem documentation and assign a revised cause of death in where there was incongruent data or where the cause of death was ill-defined. For the railway surveillance system, the cause of death information from the mortuary data was refined where possible by matching the post-mortem reports with railway records using date, age, sex, race and the location of the incident as identifiers[11].

During the main system expansion between 1999 and 2001, staff at each participating mortuary were instructed in data capture, managing the database and basic descriptive analysis using the built-in EpiInfo statistical analysis suite. Thereafter, data were usually captured on site with customised data capture files, which were either compiled in EpiInfo 6 (Dean, Dean et al. 1995) or Excel (Microsoft Corporation 2002). The exceptions were in the case of data collected by fieldworkers, or where mortuaries were under-staffed. This was an intermittent but infrequent problem in several Gauteng and KwaZulu-Natal mortuaries and was due in part to the transfer of mortuary management responsibilities from the Department of Safety and Security to the Department of Health. In such cases data were recorded manually, i.e. hand-written on printed case report forms, after which they were captured at the MRC or UNISA ISHS campuses in Cape Town or

[11] It should be noted that there were occasions where in the event of conflicting information the mortuary records were accepted as accurate. For example, the cause of death for several fatalities arising from passengers and pedestrians being caught between the train and the platform were described in the MOSA and OHSA records as ticket evasion. These were recoded as railway pedestrian or passenger injuries reaulting from being “struck-by train”.

Johannesburg respectively. Data cleaning followed the guidelines as set out in the data cleaning manualand data pertaining to the presence of alcohol and other toxins (items 18-20) were obtained in batches directly from the state chemical laboratories in Cape Town, Johannesburg and Pretoria. Researchers based at the MRC and UNISA research offices updated the relevant items using the mortuary post-mortem number to link the case report form with the laboratory results.

One aspect that had proved problematic for data capture was the incentive scheme for mortuary participation, in which mortuaries received token remuneration of R1.00 per case entered. At mortuaries attached to tertiary institutes the remuneration was paid by the Department of Health's Directorate of Mental Health and Substance Abuse into a research fund from where it was either disbursed to data capturers or used to buy equipment for the mortuary. At mortuaries where data collection and capture was performed by police personnel, mortuaries received payment in kind in the form of gifts from the MRC, as it was illegal for police officers to receive any additional remuneration. This incentive scheme, although initially a major factor in the rapid expansion and success of the system, proved unsustainable once initial grant funding had been exhausted, and did on occasion threaten the continuation of data collection at some sites.

This is no longer a problem with the Western Cape PIMSS, which was fully integrated within the FPS Information System. as the system was implemented across the province during the course of 2007 and 2008. Electronic records are reviewed and corrected by researchers based at the MRC's Burden of Disease Research Unit, and recommended enhancements and system corrections are forwarded to the FPS Director for inclusion in their ongoing system development.

5.9. Data management

The data utilised in the analysis in the results (Chapter 6) were arranged in two formats for analysis: 1) as unit records in a wide format (i.e. as individual records) for tabulations and descriptive statistics and 2) as age-specific mortality rates in a long format for multivariable analysis (see Table XII). The wide format data from which the long-format data set was constructed were largely dependent on the cleaning processes that were applied for the NIMSS city surveillance between 2001 and 2005 to enable the generation of city-specific reports and age standardised mortality rates, as described in 5.8 in this chapter.

Table XII. Example of wide format versus long-format data

Wide Format

City	Sex	Race	Age (years)	Weekday	Year of death	External cause	Apparent manner
Cape Town	M	B	23	1	2003	2	1
Durban	M	B	40	7	2002	1	1
Cape Town	F	B	34	1	2003	3	1
Pretoria	M	B	25	3	2005	1	1
Durban	M	B	18	3	2002	1	1
Johannesburg	M	B	56	2	2004	3	1
Durban	M	A	32	5	2002	2	1
Johannesburg	M	B	34	7	2003	2	1
Port Elizabeth	M	C	21	7	2004	3	1
Durban	F	A	25	3	2005	1	1

Long Format*

Age (5-year cats)	Race	Sex	Weekday	City	Year	Population	*Hom*	*Homfa*	*Homnonfa*
1	0	0	3	4	5	3791	0	0	0
7	0	1	1	1	1	5156	37	20	17
5	0	1	1	1	2	5411	42	21	21
4	0	1	2	5	2	8877	4	3	1
7	0	1	2	5	3	9075	5	0	5
7	0	1	1	1	3	5638	36	13	23
4	0	1	1	1	4	5869	22	6	16
7	0	1	1	1	5	6148	27	6	21
2	0	1	2	4	4	2975	1	0	1
1	0	1	2	4	5	2932	6	2	4

* The coding for the explanatory variables is provided in Table XI. The dependent variables (*italicised* in this table, Table XII) are counts of deaths in the particular age category.

The first step in preparing the data for the generation of city-specific reports and age standardised mortality rates was the selection of ***city-specific data***. This required the exclusion of fatalities falling outside demarcated city boundaries in order to correspond with the population data described in section 5.5. This required the tabulation of all the suburbs and towns from which cases reporting to a specific mortuary originated. "Exclusion lists" for suburbs and towns falling outside of the demarcated city boundaries were updated annually. The formulae for the inclusion of cases within the city boundaries were as follows:

- Cape Town = (Salt River Mortuary + Tygerberg Mortuary + Stellenbosch Mortuary) – Cape Town exclusion list
- Durban = (Gale Street Mortuary + Phoenix Mortuary + Pinetown/Chatsworth Mortuary) – Durban exclusion list
- Pretoria = (Pretoria Central Mortuary + MEDUNSA Mortuary + Bronkhorstspruit Mortuary) – Pretoria exclusion list
- Port Elizabeth = (Mount Rd Mortuary + Gelvandale Mortuary + New Brighton Mortuary) – Port Elizabeth exclusion list)

The assumption for the four cities above was that cases where the suburb or town was not specified would still be included in the city caseload. The situation for Johannesburg was somewhat more complicated in that the catchment areas for two mortuaries, Roodepoort and Germiston, straddled Johannesburg and neighbouring Gauteng municipalities. For cases where details regarding the place of death were missing, it could not be readily assumed that the deaths arose from within Johannesburg. Consequently an "inclusion list" was applied for Roodepoort Mortuary and Germiston Mortuary, in which cases were allocated to the Johannesburg city caseload in cases where suburbs fell *within* Johannesburg city boundaries, i.e.

- Johannesburg = (Johannesburg Mortuary + Diepkloof Mortuary – Johannesburg exclusion list) + Germiston inclusion list + Roodepoort inclusion list.

Thus, the data derived from these selection scripts for the five cities comprised the comprehensive data set from which the data analysed in this thesis were selected. The next step was to exclude all non-homicide cases. The only additional cleaning step was that the *date of death* was imputed for the 1.5 percent of cases in which *date of death* had not been recorded. The imputed date was derived from the mid-point of the dates-of-death of the preceding and subsequent post-mortems from the same facility. As all the mortuaries included in the sample had sizeable caseloads, it was typical for there to have been several post-mortems occurring on the same day and consequently the same dates-of-death for a sequence of records. The *date of death* was used to derive the *day of week* of death.

No data were imputed for *sex*, *race*, *city* or *year of death.* The *age* of the deceased was imputed for the 12 percent of cases in which the *age* was blank, but this was only undertaken after the homicide data had been contracted as series of counts for each of the dependent variables tabulated in Table XI in preparation for their transformation from a wide to a long format. The steps undertaken were as follows:

1. In STATA, *age-in-years*, a continuous variable, was recoded as a categorical variable in strata of five years (*agecat*);
2. A dummy variable (*dud*) was appended to the data set, with *dud* ==1 for each record in the data set. Thereafter duplicate records were appended with *dud* ==9 in order to ensure populated STATA tabulations for every combination of interest[12];
3. Tabulations of mortality counts by year were produced for each dependent variable in Table XI (*hom*, *homfa*, and *homnonfa*) and for every combination of explanatory; variables[13], and these tabulations were exported into Excel;
4. In Excel, the tabulations for *dud* ==9 were deleted and *dud* ==1 was retained (i.e. the real data);
5. The mortality counts were aligned with corresponding population data as described in 5.5 (and divided by 7 to take into account the scale imposed by the -*day-of-week* stratification);
6. Cells with missing age data (which had no corresponding populations) were deleted;

[12] This step was in order to ensure that STATA constructed tabulations in the exact same format without compacting the tables where there were blank rows and columns.
[13] For example, the commands to generate year-on-year counts of male and female homicides in Cape Town on Mondays were as follows: table agecat yeardead dud if city=="CAPE TOWN" & race=="C" & sex=="F" & weekday==1 & apparentma==1; table agecat yeardead dud if city=="CAPE TOWN" & race=="C" & sex=="M" & weekday==1 & apparentma==1.

7. A second set of counts derived by imputing the missing ages for each dependent variable in Table XI (*hom*, *homfa*, and *homnonfa*) according to the *city*, *race*, *sex*, *day-of-week* and *year* specific death-age distribution[14], with the new dependent variables identified with the suffix "*m*", i.e. *mhom*, *mhomfa* and *mhomnonfa* respectively;
8. The data were recoded according to the dummy variables listed in Table XI in section 5.5 and then exported into STATA; and

In STATA, the data were transformed from a wide format into a long format using the following command: reshape long *hom homfa homnonfa mhom mhomfa mhomnonfa pop*, i(*age race sex dow city*) j(*year*) where, for example, *mhom* was the revised variable for *hom* with missing ages imputed.

5.10. Data analysis

Age standardisation in this thesis followed the same direct age standardisation method used in the NIMSS. This was applied to the Port Elizabeth homicide data and for all five cities combined. As in the NIMSS, age adjusted death rates and standard errors were calculated as follows:

Age –adjusted death rate $\sum_i \frac{P_{si}}{P_s} R_i$ $(R) =$

$$SE(R) = \sqrt{\sum_i \left(\frac{P_{si}}{P_s}\right)^2 \mathrm{var}(R_i)} = \sqrt{\sum_i \left(\left(\frac{P_{si}}{P_s}\right)^2 \left(\frac{R_i^2}{D_i}\right)\right)}$$

where *Ri* is the age-specific death rate for the *i*th age group, *Psi* is the standard population for age-group *i*, *Ps* is the total World Standard population (all ages combined), and *Di* is the number of deaths for the *i*th age group[15].

[14] This was based on the assumption that missing ages occurred randomly within city-race-sex-day-year categories and that deaths with missing ages would follow the same age distribution as where ages were available. The basis for the categorisation of age in 5-year age categories and the assumption regarding the distribution of missing ages and the impact of the imputation is addressed specifically in section 6.2.1 of the results.
[15] See Kung, Hoyert et al. (2008)

The relative standard error for age-specific death rates was calculated as:

$$\mathrm{RSE}(Ri) = 100\sqrt{\frac{1}{D}}$$

Exploratory analysis of the data entailed basic tabulations and frequency counts of the various explanatory variables for homicide as well as graphical representation of the data.

Multivariable analysis was utilised to ascertain the role of different independent variables in explaining variability across locations and time for the cause of death categories under investigation (i.e. homicides, firearm homicides and non-firearm homicides). A generalised linear model (GLM) with Poisson family was constructed that included the following covariates: *age*, *sex*, *race*, *city*, *year of death* and *day of week* as well as *population* as the exposure variable. The Poisson model was preferred to other models such as the negative binomial model as it enabled comparisons of rates across categories relative to a common population base. The assumption was that the mortality counts for the dependent variables as listed in Table XII were Poisson distributed, i.e. with the characteristic that, per person-year, mean=variance=μ, i.e.:

ln(μ) = linear combination of coefficients for *age*, *sex*, *race*, *city*, *year of death*, *day of week* (with interactions) = Xβ

Thus, $e^{X\beta}$ was the Poisson mean or the mortality *rate* per person-year and comparisons of β coefficients allows comparisons of rates across categories. Because the death counts for each covariate pattern correspond to different population sizes, *population* as derived in 5.5 was assigned as the exposure variable.

The GLM was parameterised using a log link and robust estimation of standard errors was used to adjust for over-dispersion. The fit across models was assessed using the AIC (the Akaike information criterion) and BIC (the Bayesian Information Criterion). For individual models the impact on goodness-of-fit of including additional variables and interaction terms was assessed by comparing the ratio of the deviance versus residual degrees of freedom. For both AIC and BIC lower values and lower ratios of deviance versus residual degrees of freedom indicated a better fit. The *age* variable, which was initially stratified according to eighteen 5-year age categories due to the inaccuracy in the recording of age, was subsequently fitted with splines at 15, 30 and 60 years in order to represent the relationship of age to log(homicide rate) parsimoniously, while capturing the non-linearity. The distribution of age data and the management of missing data is described in more detail in section 6.2.1 of the Results chapter.

This analysis is certainly more substantial than anything that had been attempted previously in the outputs of the surveillance system annual reports. To some extent the complexity of the analysis in the latter had varied according to the objectives of the specific surveillance studies and the intended audience for the outputs that were produced. The standardised annual reports for the Cape Town city-wide pilot study and the NIMSS constituted the most basic level of analysis, and mainly included counts and percentages to demonstrate the demographic and spatial distribution of mortality and the main external causes of injury according to each apparent manner of death. For both the Cape Town city-wide pilot and railway injury surveillance studies, potential years of life lost (YLL) were calculated by totalling the number of years that each death was "premature" (i.e. the number of years before the age of 65 years) (Katzenellenbogen, Joubert et al. 1991). The most sophisticated descriptive methods in the standardised annual reports that were produced for the Cape Town city-wide pilot study and the NIMSS comprised potential years of life lost (YLL), which were calculated for the Cape Town citywide pilot from 1994 to 1995 and age standardised rates, which appeared in later versions of the NIMSS city-level surveillance from 2004 as well as in the Cape Town citywide pilot . The beneficiation of death counts into city-specific mortality rates provided a description of risk at a population level, which in itself facilitated more complex comparative analysis.

Other less routine analysis of the NIMSS data has previously been undertaken in cases where the surveillance data were complemented by other data sources and utilised for specialised studies. For example, fatal railway injuries were matched with injury report forms from Cape Metrorail to assess levels of underreporting and to obtain further information about the circumstances relating to the injury event (Lerer, Matzopoulos 1996). This prompted the development of a subsequent case-control study, which assessed the relationship between alcohol and rail fatalities (Matzopoulos, Peden et al. 2006). Similarly, NIMSS data were complemented by data from a Cape Town cross-sectional study of fatal and non-fatal injury cases (Peden, Marais et al. 1997), which enabled the calculation of national disability-adjusted life year (DALYs) rates alongside standard mortality measures (Norman, Matzopoulos et al. 2007) (see section 5.11 in this chapter - Estimation).

NIMSS data were also utilised in two PhDs with publications included focussing on suicide (Burrows) and burns (Van Niekerk). Two of Burrows' papers focussed on the city of Pretoria and included data from others sources in addition to the NIMSS. The first paper compared suicide data from the mortuary surveillance data in Pretoria in 2000 with final verdicts from inquest courts to determine the accuracy of the suicide mortality data recorded in the NIMSS (Burrows, Laflamme 2007). The study confirmed the slow nature of the inquests process with only two-thirds of cases finalised 5 years after the death had occurred. In the second, an ecological study, the NIMSS place of death variable in Pretoria was linked with geographical data from the Census to assess the association of the living circumstances of the deceased on suicide mortality (Burrows, Laflamme 2005).

In addition to a qualitative study assessing medical practitioners' perspectives of the determination of suicide cases (Burrows, Laflamme 2007), two other papers relied primarily on bivariate and trivariate analytic techniques. One paper used the full NIMSS data set to describe the socio-demographic distribution and to assess whether suicide cases were disproportionately represented among various sub-groups of interest (e.g. males vs females, Asians vs Blacks vs Whites vs Coloureds) compared to other manners of death (homicide vs unintentional vs suicide) (Burrows, Vaez et al. 2003). The other utilised age standardised rates from six cities for 2001 to 2003 (including east London), similar to those provided in the NIMSS annual reports, to assess whether there were significant differences in the distribution of suicides by sex, race and mechanism of death according to the city of death (Burrows, Laflamme 2006). Thereafter Burrows et al also conducted a logistic regression on these data to explore the role of age, race, and geographical location as predictors of suicide among males and females in these cities (Burrows, Vaez et al. 2007).

Van Niekerk's PhD focused on burns in Cape Town, but only one of the papers focused on burn mortality and utilised NIMSS data for the period 2001 and 2004. Among the analysis techniques were simple descriptive statistics such as frequencies for day, month and time of burn occurrence, and the proportion of fatalities above the legal blood alcohol limit by age category. The study also replicated the calculation of age standardised rates as had been applied in the NIMSS annual report for 2004 and included a Poisson model with age group, gender and population group (i.e. race) as the main effects (Van Niekerk, Laubscher et al. 2009)

5.11. Estimation

In addition to the current analysis, which provides estimates of homicide rates as per the GLM modelling described in section 5.10, the injury mortality data from mortuary-based injury surveillance systems have in the past been used to estimate provincial and national mortality in South Africa. In the first National Burden of Disease (NBD) study, which was based on the Global Burden of Disease methodology, Bradshaw et al (2003) used the cause of death profile arising from the NIMSS to calculate initial estimates of burden of injury mortality in South Africa for 2000.

Although the NIMSS sentinel mortuaries were located predominantly in large urban areas, suggesting that the data were more reflective of urban rather than rural injury rates, the profile in terms of the age and sex distributions for the major causes of injury deaths were found to be similar to data arising from other sources. These included the injury cause of death distributions from the 1988/1989 Stats SA death data, the re-analysed 1990 Cape Metropole Study (Norman 2002) and the Agincourt and Hlabisa surveillance systems (Bradshaw, Groenewald et al. 2003). The profile was applied to the estimated total number of injury deaths, which was based on the Actuarial Society of Southern Africa's (ASSA) estimate of the injury death percentage of total deaths (Statistics South Africa 2005). The ASSA estimates were derived from vital registration data and also included a population model to provide revised estimates of the national population size in 2000. The NBD analysis provided estimates of premature mortality due to injury, as measured in years of life lost (YLL). The YLL estimates along with estimates of the years lived with disability (YLDs), which were based on data from a Cape Town cross-sectional study of fatal and non-fatal injury cases (Peden, Marais et al. 1997), enabled the calculation of national disability-adjusted life year (DALYs) rates (Norman, Matzopoulos et al. 2007).

An ancillary study to the NBD , which provided provincial estimates adopted a similar approach. The provincial totals were estimated from the percentage of injury deaths observed in a 12 percent sample of deaths stratified by sex, 5-year age groups and province that had been supplied by the Department of Home Affairs. The NIMSS injury profile was applied to the total number of injury deaths estimated for each group occurring in each province .

In a related study, NIMSS data were used to estimate the magnitude and characteristics of the national injury burden in South Africa within a global context (Norman, Matzopoulos et al. 2007). National age standardised mortality rates per 100,000 population were calculated using the standard world population for each apparent manner of death and compared with geographical regional estimates from the Global Burden of Disease 2000 database, version 1 (Global burden of disease 2000, Version 1 estimates, Murray, Lopez et al. 2001).

Researchers will soon be in a position to test the assumptions about the similarity between rural and urban injury profiles with the availability of data from two additional sources. The Western Cape PIMSS provides the first comprehensive provincial injury mortality profile and the forthcoming Injury Mortality Surveillance study is a national retrospective study that includes among its objectives the provision of a metro and non-metro profile of injury incidence for 2009 by age, sex and cause. These data are likely to enhance future national burden of injury estimation.

5.12. Ethics and confidentiality

The analysis in this thesis relied exclusively on secondary data either from the post-mortem investigation process or the Census. Whereas the surveillance system data from which the data in this thesis are drawn included identifiers in the form of death register numbers to ensure completeness and to assist with data cleaning, for the analysis in this study all identifying information was redacted. The study was approved by the University of Cape Town's Health Sciences Faculty Research Ethics Committee (Ref: 448/2007) and permission to use the data for the purpose of this study was granted by the National Department of Health. The approval letters are included in Appendices II and III respectively.

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CHAPTER 6: RESULTS

These results are based primarily on an analysis of data from five cities over a five year period as described in section 5.3. In this chapter, section 6.1. provides an overview of the data coverage and section 6.2. a description of the distribution of the different explanatory variables for homicide incidence. In order to demonstrate the utility of the mortuary-based injury surveillance system, section 6.3. addresses the three hypotheses and various sub hypotheses set out in the Aims and Objectives (chapter 4).

6.1. Data coverage

Homicides were selected from the five cities with full mortuary coverage between 2001 and 2005 inclusive, i.e. Cape Town, Durban, Johannesburg, Port Elizabeth and Pretoria (Table XIII).

Table XIII. Homicide for five cities, 2001-2005 (N= 36,706)

City	Number of cases / year					
	2001	2002	2003	2004	2005	Total
Homicide	8164	8249	7360	6492	6441	36706
Cape Town	2470	2448	2188	1810	1954	10870
Durban	2081	2167	2077	1890	1866	10081
Johannesburg	2247	2262	1872	1540	1429	9350
Port Elizabeth	731	752	689	659	731	3562
Pretoria	635	620	534	593	461	2843

Comparison of these data with corresponding police data for the period April 2001 to March 2005 (South African crime statistics by province: 2005) to coincide with the police reporting period (Table VII in Chapter 3) is shown in Table XIV. In three of the cities (Durban, Johannesburg and Pretoria) the discrepancies were negligible, with less than two percent variation between the mortuary and police estimates. This could be ascribed to slightly different catchment areas and timing differences relating to registration of deaths and murder dockets. In Cape Town, where the police recorded four percent fewer homicides, underreporting by the police cannot be ruled out. It may also be possible that the catchment areas of the two systems were not well-matched especially with expanding settlements on the urban periphery complicating the allocation of deaths to different jurisdictions. In the case of the mortuary data, deaths from within the Cape Town metropolitan area that were autopsied in Stellenbosch were included in the sample, whereas the same might not have been the case with police data.

In Port Elizabeth, where the police routinely recorded more homicides data than were recorded by the mortuaries it may be that police catchment area for homicide extended further outside the city boundaries than the mortuaries. Although the Port Elizabeth data indicate that underreporting by the mortuaries cannot be ruled out there does not appear to be any substantial or systematic underreporting of homicide data across the five cities that form part of this study and consequently the mortuaries appear to be highly sensitive in capturing homicide data. The comparison suggests that the mortuary-based data provide a reliable estimate of homicide in the five cities and also serve to validate the accuracy of police murder statistics, at least in urban areas.

Table XIV. Comparison of police and mortuary data from the period April 2001 to March 2005 across five cities

	Cape Town	Durban	Johannesburg	Port Elizabeth	Pretoria	All five cities
2001/2002						
Police data	2296	2132	2297	779	605	8109
Mortuary data	2538	2132	2356	737	598	8361
% difference *	-10	0	-3	6	1	-3
2002/2003						
Police data	2619	2163	2178	831	627	8418
Mortuary data	2546	2125	2164	791	633	8259
% difference *	3	2	1	5	-1	2
2003/2004						
Police data	1863	2089	1817	735	586	7090
Mortuary data	1902	2040	1819	647	546	6954
% difference *	-2	2	0	14	7	2
2004/2005						
Police data	1757	1931	1596	786	544	6614
Mortuary data	1889	1883	1550	706	555	6583
% difference *	-7	3	3	11	-2	0
All four years						
Police data	8535	8315	7888	3131	2362	30231
Mortuary data	8875	8180	7889	2881	2332	30157
% difference *	-4	2	0	9	1	0

* i.e. of police relative to mortuary data -no of police records / no of mortuary records x 100-100

Age standardised homicide rates derived from the mortuary data reflected the exceptionally high homicide rates in South Africa's five largest cities (Table XV)[16]. The homicide rates in Cape Town and Port Elizabeth and Durban were considerably higher than the national average estimated by Norman et al. (2007) and there were also significant differences between the cities between 2001 and 2005. Specifically,

- Cape Town and Port Elizabeth experienced significantly higher homicide rates than Durban, Johannesburg and Pretoria on average;
- Durban, in turn, had significantly higher homicide rates than Johannesburg and Pretoria on average; and
- Johannesburg, in turn, had significantly higher homicide rates than Pretoria on average.

[16] The rates for Cape Town, Durban, Johannesburg and Pretoria were published in the 2005 NIMSS annual report (Prinsloo 2007). The rates for Port Elizabeth were calculated specifically for this analysis according to the same method.

In addition, the ranking of the cities in terms of their safety changed over the five year period, with Port Elizabeth surpassing Cape Town as the city with the highest homicide rate from 2004 onwards. The extent to which these differences are dependent on the various covariates, specifically *age*, *sex*, *race*, *city*, *year of death* and *day of week* is described in detail in section 6.3. The distribution of these covariates is summarised in section 6.2.

Table XV: Age-standardised homicide rates for South Africa's five largest cities, 2001-2005

		2001	2002	2003	2004	2005	Average
Cape Town	Rate*	77.5 (74.4 - 80.6)	74.4 (71.4 - 77.3)	65.7 (62.9 - 68.5)	53.9 (51.4 - 56.4)	59.5 (56.9 - 62.1)	66.0 (64.7 - 67.2)
	Rank	1	1	1	3	2	1
	Ratio#	8.8	8.5	7.5	6.1	6.8	7.5
Durban	Rate*	63.1 (60.4 - 65.9)	65.0 (62.2 - 67.8)	60.9 (58.2 - 63.6)	55.0 (52.5 - 57.6)	53.9 (51.4 - 56.4)	59.6 (58.4 - 60.8)
	Rank	3	3	3	2	3	3
	Ratio#	7.2	7.4	6.9	6.3	6.1	6.8
Johannesburg	Rate*	59.9 (57.3 - 62.5)	57.5 (55.0 - 60.0)	48.8 (46.5 - 51.1)	39.2 (37.1 - 41.2)	35.7 (33.8 - 37.6)	48.0 (47.0 - 49.0)
	Rank	4	4	4	4	4	4
	Ratio#	6.8	6.5	5.5	4.5	4.1	5.5
Port Elizabeth	Rate*	68.7 (63.7 - 73.8)	70.7 (65.6 - 75.8)	63.3 (58.5 - 68.0)	59.5 (55.0 - 64.1)	66.5 (61.7 - 71.3)	65.7 (63.5 - 67.9)
	Rank	2	2	2	1	1	2
	Ratio#	7.8	8.0	7.2	6.8	7.6	7.5
Pretoria	Rate*	29.1 (26.8 - 31.4)	27.8 (25.6 - 30.1)	23.3 (21.3 - 25.3)	25.8 (23.6 - 27.9)	20.2 (18.3 - 22.1)	25.2 (24.2 - 26.1)
	Rank	5	5	5	5	5	5
	Ratio#	3.3	3.2	2.6	2.9	2.3	2.9
Combined	Rate*	60.3 (58.9 - 61.6)	59.3 (58.0 - 60.6)	52.4 (51.2 - 53.6)	45.7 (44.6 - 46.8)	45.4 (44.3 - 46.5)	52.5 (51.9 – 53.0)
	Ratio#	6.8	6.7	6.0	5.2	5.2	6.0

* Age standardised mortality rate per 100,000 population (with 95% CI) based on the WHO World Standard population.
\# South African rate versus global age standardised rate of 8.8 per 100,000 population from (Mathers, Inoue et al. 2002).

6.2. Distribution of explanatory variables

It was shown in the literature review (sections 2.1. to 2.3) that *age*, *sex*, *race*, *city*, *year of death*, *day of week* and *alcohol-relatedness* were all potentially important contributory factors for homicide. Univariate analysis for each variable in the data set is shown in Table XVI, except *age*, for which there were too many values for tabulation. The age-distribution is described in more detail in section 6.2.1.

Table XVI. Univariate analysis of homicide (N = 37,067)

Variable	n (%)
Sex	
female	4,431 (12)
male	32,431 (87)
unknown	205 (1)
Race	
African	29,179 (79)
Asian	835 (2)
Coloured	5,299 (14)
White	1,466 (4)
unknown	288 (1)
City	
Cape Town	10,996 (30)
Durban	10,118 (27)
Johannesburg	9,485 (26)
Port Elizabeth	3,612 (10)
Pretoria	2,856 (8)
Year of death	
2001	8,227 (22)
2002	8,296 (22)
2003	7,442 (20)
2004	6,525 (18)
2005	6,577 (18)
Day of week	
Sunday	7,578 (20)
Monday	4,572 (12)
Tuesday	3,718 (10)
Wednesday	3,608 (10)
Thursday	3,518 (9)
Friday	5,144 (14)
Saturday	8,929 (24)

Alcohol	
0.00 g/100ml	10766 (29)
>0.00 g/100ml	11836 (32)
unknown	14465 (39)

Graphical inspection for each covariate of interest stratified by city showed that the distributions were not uniformly distributed across the cities. For example, analysis by sex showed that males accounted for a higher proportion of homicide in Cape Town than in Pretoria (Figure 4). With regards to race, Coloureds accounted for a higher percentage of homicides in Cape Town and Asians accounted for a higher percentage in Durban than in other cities (Figure 5). Similarly analysis of homicide by age, sex and city showed that the homicide peak among young males occurred at younger age in Cape Town and was less pronounced in Pretoria (Figure 6). Homicides were more concentrated on weekends in Cape Town and Port Elizabeth than in the other cities (Figure 7). This was also consistent with the alcohol relatedness of homicides with these two cities, particularly Port Elizabeth, reporting the highest percentage of alcohol-positive homicides (Figure 8). The distribution of firearm (Figure 9) and non-firearm homicide by year of death (Figure 10) differed in that there were notable declines in the firearm homicides across most cities, whereas the number of non-firearm homicides remained constant.

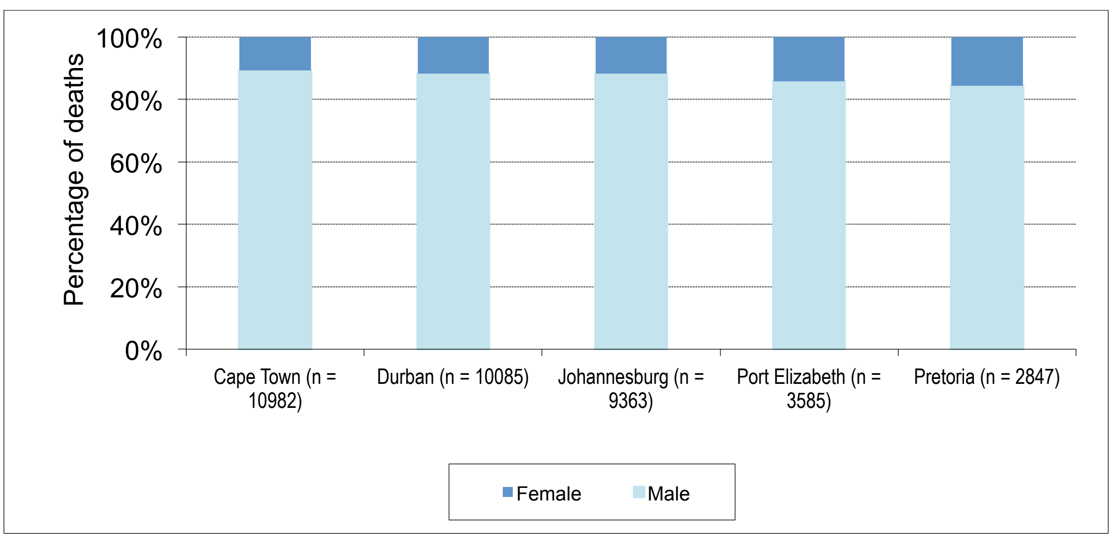

Figure 4. Distribution of homicide by sex in each city (N = 36,862)

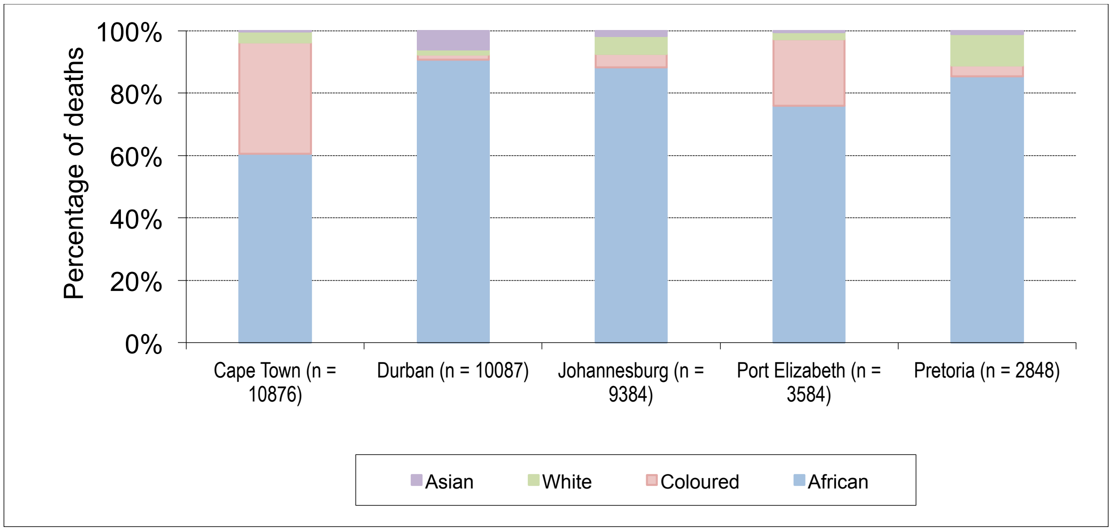

Figure 5. Distribution of homicide by race in each city (N = 37,067)

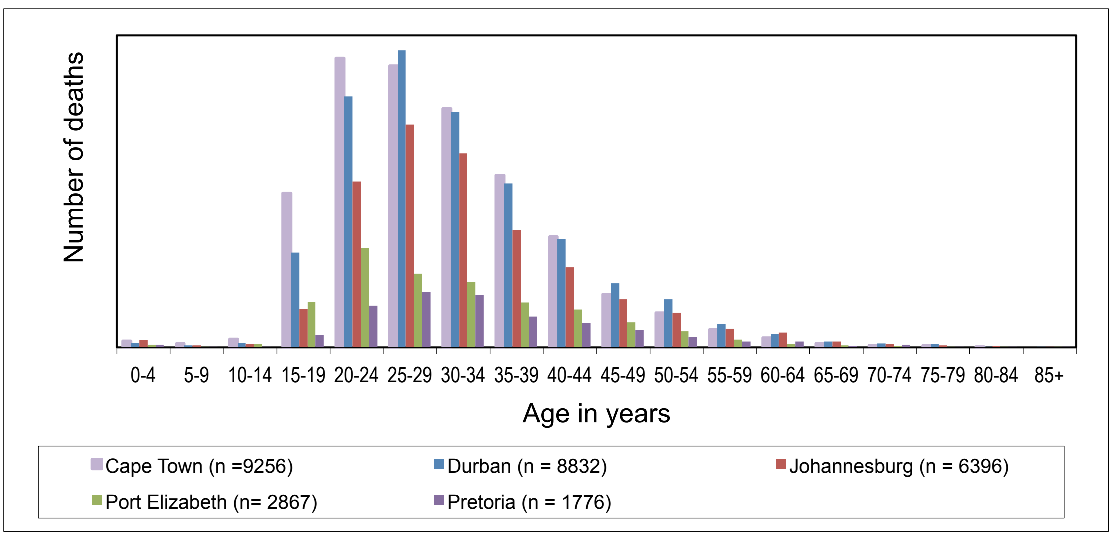

Figure 6. Distribution of homicide by age among males in each city (N = 29,127)

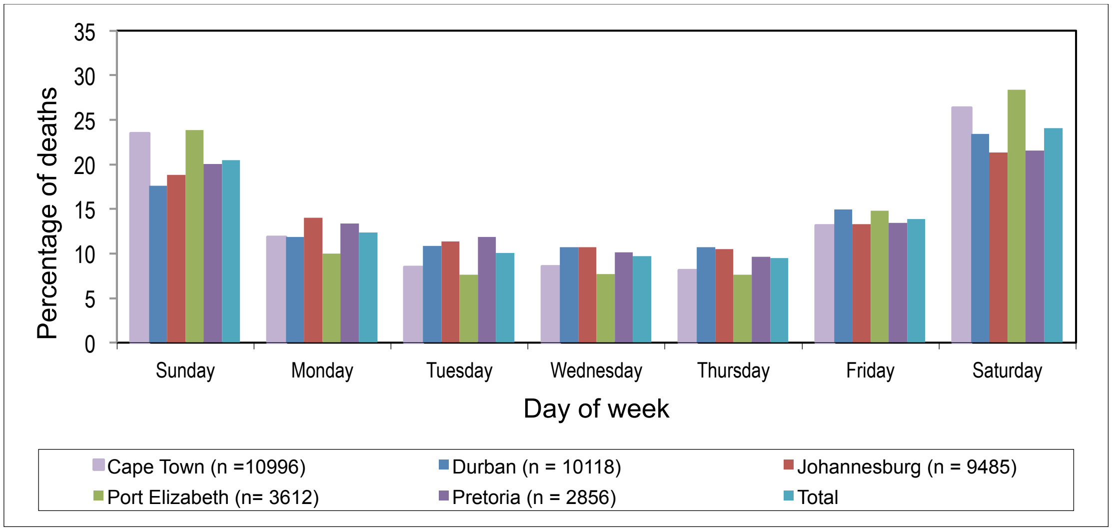

Figure 7. Distribution of homicide by day of week in each city (N = 37,067)

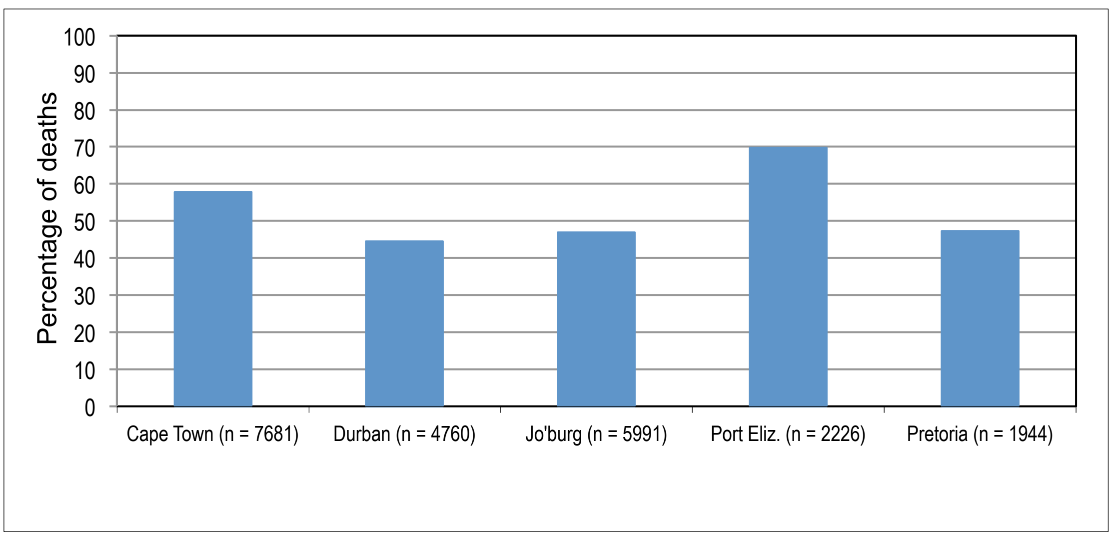

Figure 8. Distribution of alcohol-positive homicides by city (N = 22,602)

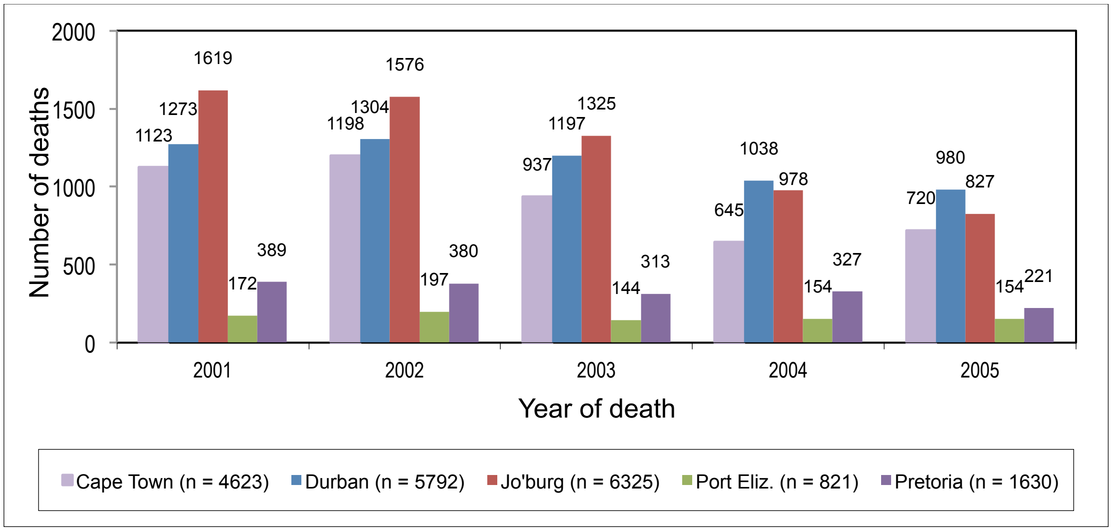

Figure 9. Distribution of firearm homicide in each city (N = 19,191)

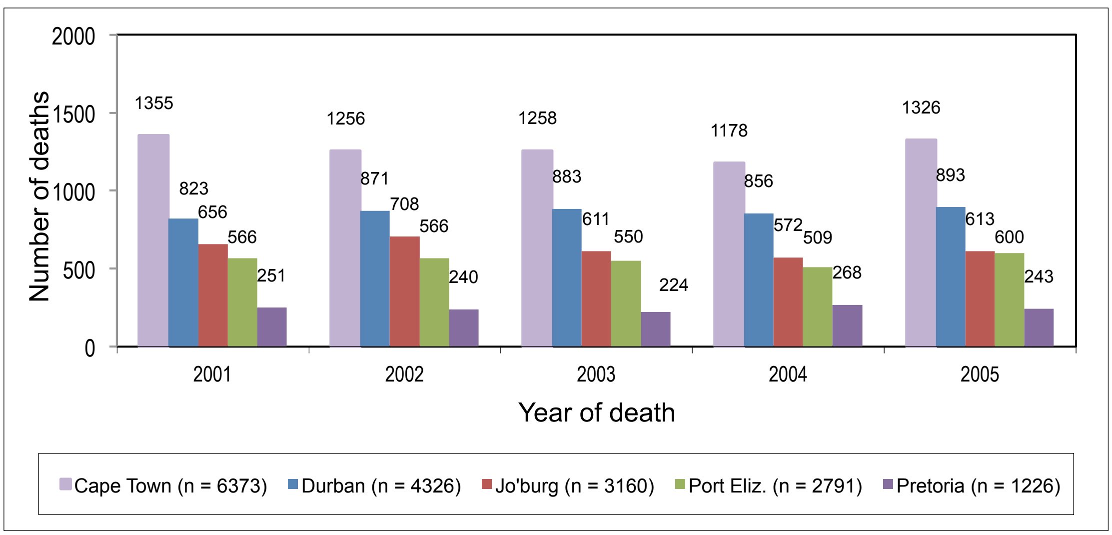

Figure 10. Distribution of non-firearm homicide in each city (N = 17,876)

Clearly some of these features might be explained by demographic differences in the underlying populations as *age*, *sex* and *race* were not evenly distributed across cities. Thus, it was necessary to include appropriate population (denominator) data for each city that accurately described the population distribution according to these key demographic variables that would enable the calculation of mortality rates and, moreover, multivariable analysis that could simultaneously take the impact of covariates into account.

The subsequent multivariable analysis enabled an enhanced understanding of the contribution of each of these explanatory variables to mortality rates and, in particular, whether each covariate was independently associated with homicide or whether these associations could be fully or partially explained by confounding due to one or more of the other explanatory variables.

6.2.1. Distribution of age data and management of missing data

A summary of the completeness of the various data included in the modelling is shown in Table XVII. The dependent variables in the multivariable models, i.e. homicide, firearm homicide and non-firearm homicide, were derived from the *apparent manner of death* and the *external cause of death*. Where the *external cause of death* was missing, cases were recoded as "external cause unknown". As missing values for *external cause*, *sex* and *race* accounted for less than one percent of total cases, the effect on the modelling was expected to be trivial and no adjustment for these missing values was deemed necessary.

Table XVII. Summary of data completeness-five cities, 2001-2005 (N= 37,067)

Variable	Missing values-*No (%)*
City	0 (0%)
Year of death	0 (0%)
Day/date of death	0 (0%)
Apparent manner of death	0 (0%)
External cause of death	166 (<1%)
Sex	205 (<1%)
Race	0 (0%)
Age in years	3841 (10%)
Alcohol-relatedness	14,465 (39%)

For *alcohol-relatedness*, data were only available for 61 percent of homicides and so alcohol was excluded as a covariate. However, as shown in Figures 7 and 8, day of week was a useful indicator of drinking patterns and the alcohol-relatedness of homicide. The reasons for high missing values of the alcohol data could be ascribed to the fact that alcohol testing was not routinely performed for minors younger than 18 years (about 5 percent of cases), and that blood alcohol measurements were not routinely collected for deaths due to the late effects of the injury (more than 6 hours after. It was also possible that as alcohol testing was performed outside the mortuaries at the state chemical laboratories not all the results would have reached the mortuaries in time for inclusion in the NIMSS database. This is supported by a brief analysis of alcohol data completeness by city (Figure 11), which shows that there was considerable variation in completeness between cities. Completeness was highest in the three cities in which the laboratories performing alcohol content were located: Cape Town (70 percent), Pretoria (68 percent) and Johannesburg (63 percent). Completeness was lower in Port Elizabeth (62 percent) and particularly in Durban (47 percent), as both cities were reliant on blood alcohol analysis being performed and returned from the three laboratories in Cape Town, Pretoria and Johannesburg.

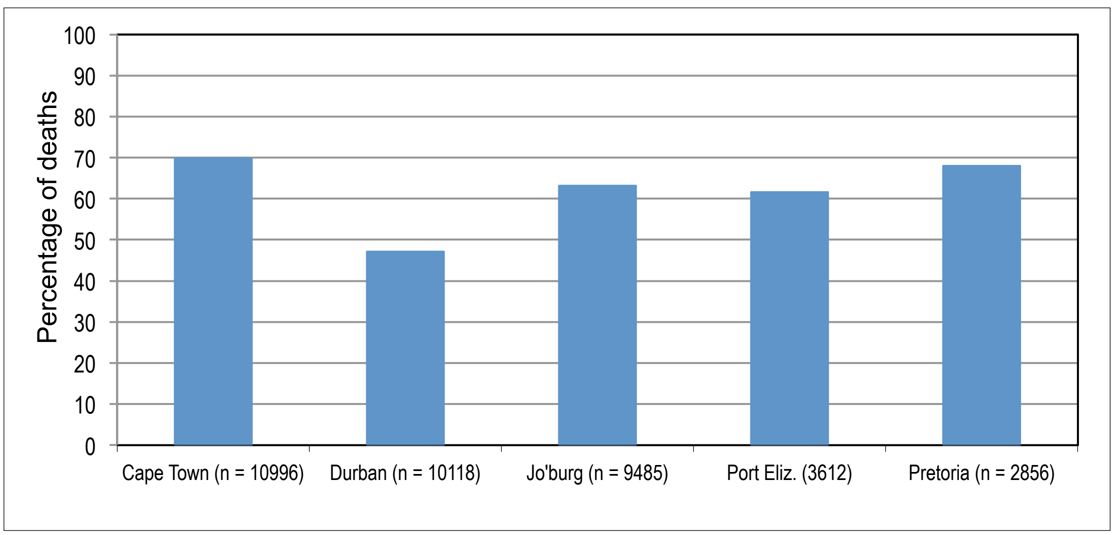

Figure 11. Completeness of alcohol data for homicide by city (N = 37,067)

There was a large number of deaths with no recorded *age* - 10 percent of the total sample. There were several reasons as to why this might have occurred. For example, data capturers may not have been as thorough in every mortuary and omitted to always record ages or the electronic data files may have become corrupted (e.g. if age in years was calculated according to the difference between the date of birth and the date of death). Also, it was clear that there were sharp peaks indicating 5 year digit preference, e.g. at 20, 25, 30 years, etc. This was most probably as a result of pathologists estimating ages in the case of unidentified cases and rounding the age in years to the closest multiple of 5 (Figure 12). It was also conceivable that some pathologists would have been reluctant to estimate ages and might instead have recorded *age* as unknown.

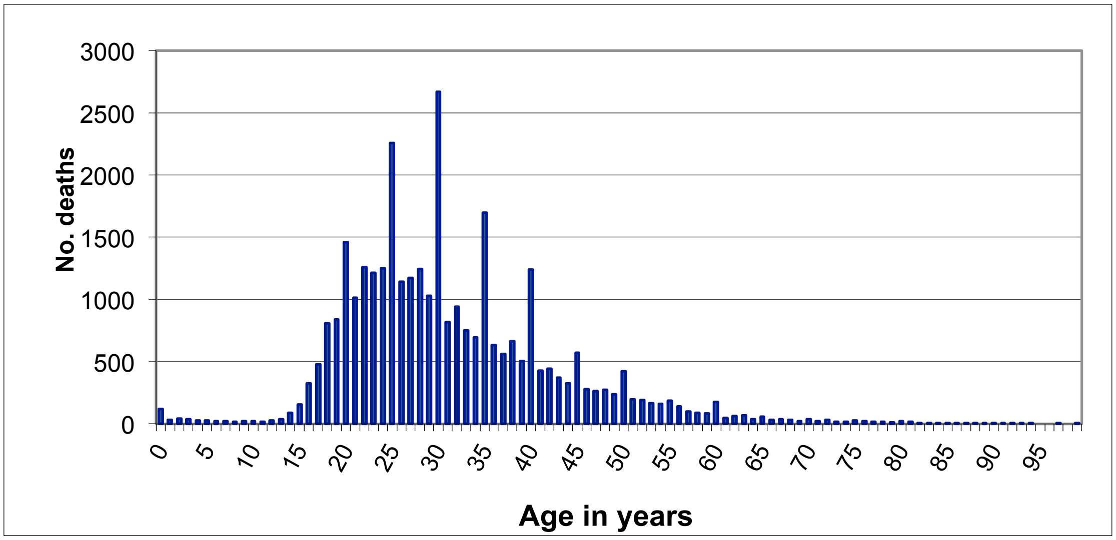

Figure 12. Age of homicide in five cities, 2001-2005 (N=33,226) - excludes missing age

The application of a 5-year moving average to the age of the deceased (Figure 13) as well as the analysis of age by five-year age categories (Figure 4) provided a clearer indication of the effects of age and the peak for young adults.

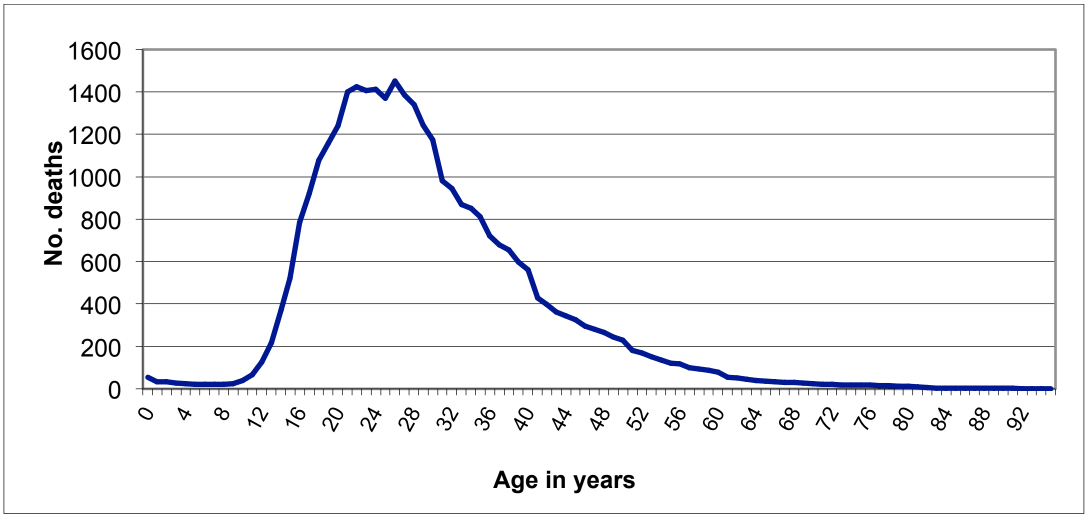

Figure 13. Age of homicide in five cities – five-year moving average, 2001-2005 (N=33,226) - excludes missing age

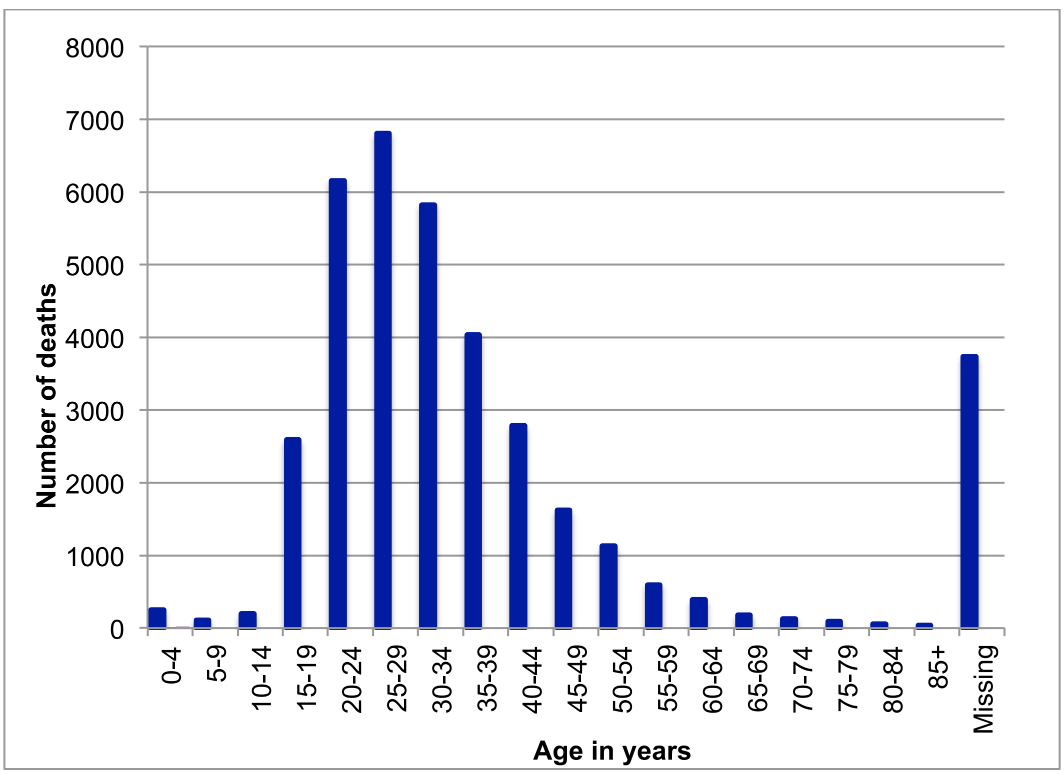

Figure 14. Age of homicide in five-year age categories in five cities, 2001-2005 (N=37,067)

In order to address the possible under-estimation of age-specific mortality rates due to records with missing age values, revised counts were calculated for each cause of death (*homicide*, *firearm homicide* and *non-firearm homicides*) by imputing the missing ages according to the *city-race-sex-year-day of week* specific distribution. The assumption was that missing age data occur randomly and that deaths with missing ages would thus follow the same age distribution as deaths where ages were available. This allocation is shown graphically in Figure 4.

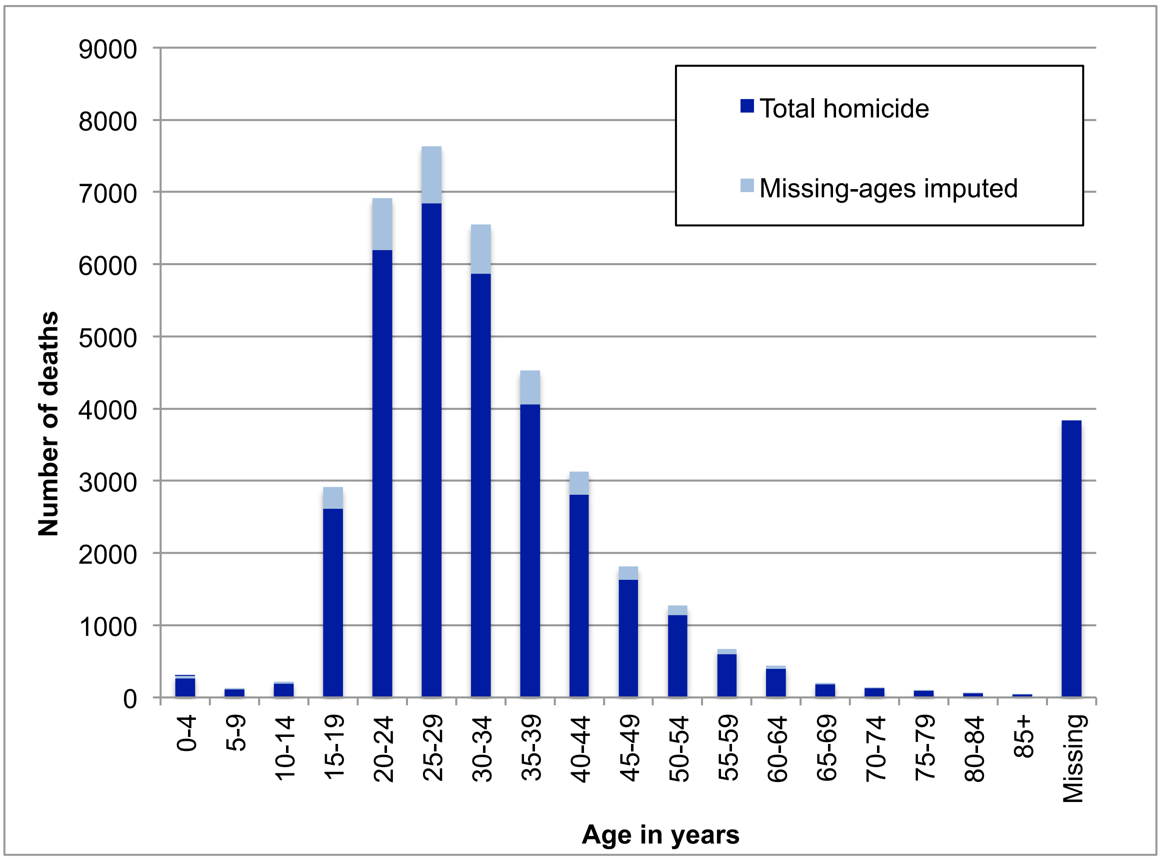

Figure 15. Age of homicide in years five cities – five-year age categories, 2001-2005 (N=37,067) with missing ages imputed according to known-age-at-death values for the entire sample

6.3. Multi-variable analysis of homicide rates

For homicide the age pattern shown in Figures 13, 14 and 15, with a sharp increase in homicide risk from the age of 15 years and a peak among young adults between the ages of 20 and 30 years was consistent across all five cities (Figure 16) and also consistent with aggregated global homicide data in low-and middle-income countries (Mathers, Inoue et al. 2002).

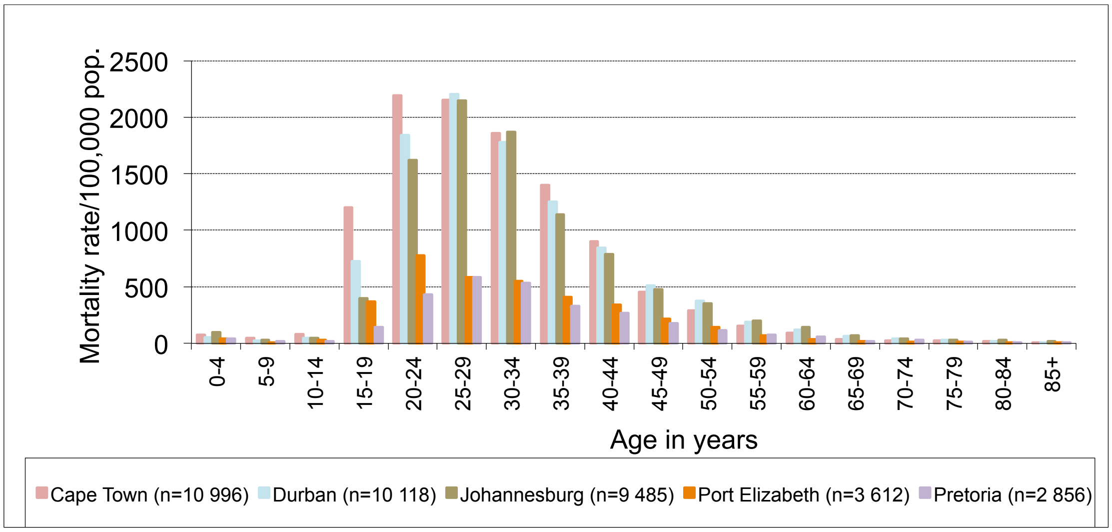

Figure 16. Homicide by age with missing age values imputed - five cities, 2001-2005 (N=37,067)

This pattern was also mirrored in the age-specific homicide *rates* for each city, although the conversion of the counts to rates altered the ranking of the cities. Homicide *rates* were noticeably higher in Cape Town, Durban and Port Elizabeth than in Johannesburg and particularly Pretoria. These differences highlighted the importance of considering the underlying population sizes when analysing homicide risk.

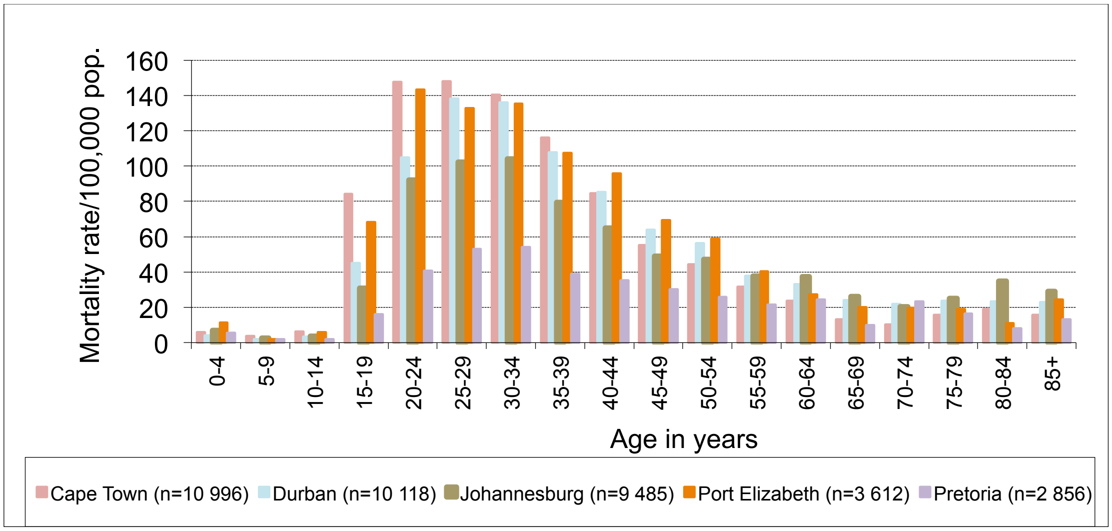

Figure 17. Average homicide rate by age with missing age values imputed - five cities, 2001-2005 (N=37,067)

6.3.1. Explanatory variables as independent predictors (Hypothesis 1)

A generalised linear model (GLM) with Poisson family was constructed, as described in section 5.10, that included the following covariates: *age*, *sex*, *race*, *city*, *year of death* and *day of week*. As it was clear *a priori* that the relation of age to homicide rate was non-linear and because of the digit-preference for age of the deceased corresponding with multiples of five, *age* was first defined as a categorical variable in the GLM (model 1). An alternative approach, while still considering age in 5-year categories, was to apply linear splines with knots at 15 years, 30 years and 60 years (model 2 in Table XVIII), based on the ages at which the total number of homicides in the sample increased rapidly (15-years), the total number of homicides peaked (30 years), and the total number of homicides declined more slowly (60 years) – see Figure 18.

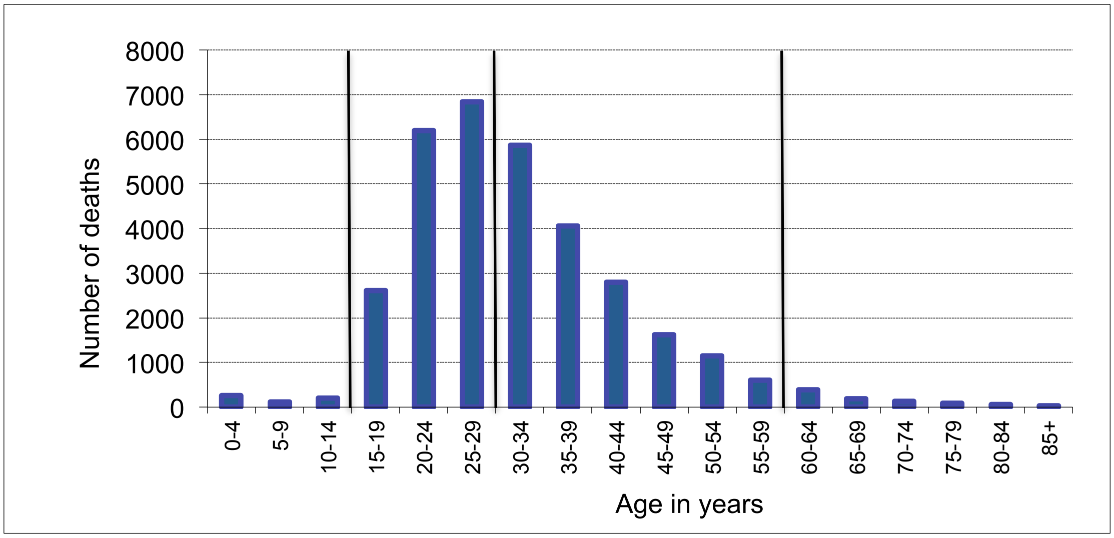

Figure 18. Homicide by age - five cities combined, 2001-2005 (N=37,067) with imputed missing age values[17] and splines indicated at 15, 30 and 60 years

These splines represented the relationship of age to $\log_e$(homicide rate) more parsimoniously (i.e. with only four parameters). Table XVIII summarises the two crude (i.e. unadjusted for other covariates) age models.

[17] Missing ages were imputed according to the known-age at death values for the entire sample.

Table XVIII. Crude models for age-specific homicide rate

(Model no) covariates included	*Log likelihood*	*Dev.*	*Resid. df*	*AIC*	*BIC*
(1) *age* (categorical)	-36970	56832	25182	2.94	-198378
Parameter[18]	Coefficient (95% CI)	P-val			
Age (0-4) [constant]	*-9.94 (-10.07:-9.81)*	*< 0.01*			
Age (5-9)	*-0.84 (-1.07:-0.61)*	*< 0.01*			
Age (10-14)	*-0.26 (-0.46:-0.07)*	*0.01*			
Age (15-19)	*2.24 (2.05:2.42)*	*< 0.01*			
Age (20-24)	*2.96 (2.79:3.14)*	*<0.01*			
Age (25-29)	*3.05 (2.88:3.23)*	*<0.01*			
Age (30-34)	*3.04 (2.86:3.21)*	*<0.01*			
Age (35-39)	*2.81 (2.64:2.98)*	*<0.01*			
Age (40-44)	*2.58 (2.42:2.75)*	*<0.01*			
Age (45-49)	*2.27 (2.1:2.44)*	*<0.01*			
Age (50-54)	*2.14 (1.98:2.31)*	*<0.01*			
Age (55-59)	*1.81 (1.64:1.98)*	*<0.01*			
Age (60-64)	*1.69 (1.51:1.86)*	*<0.01*			
Age (65-69)	*1.24 (1.03:1.45)*	*<0.01*			
Age (70-74)	*1.2 (0.98:1.42)*	*<0.01*			
Age (75-79)	*1.28 (1.03:1.53)*	*<0.01*			
Age (80-84)	*1.33 (1.02:1.63)*	*<0.01*			
Age (85+)	*1.34 (0.99:1.69)*	*<0.01*			
(2) *age* (continuous/splined)	-38179	59248	25195	3.03	-196093
Parameter[3]	Coefficient (95% CI)	P-val			
Age (0-4) [constant]	*-10.65 (-10.83:-10.46)*	*<0.01*			
Age (5-14)	*1.04 (0.91:1.17)*	*<0.01*			
Age (15-29)	*0.62 (0.57:0.68)*	*<0.01*			
Age (30-59)	*-0.23 (-0.25:-0.21)*	*<0.01*			
Age (60+)	*-0.17 (-0.21:-0.13)*	*<0.01*			

A graphical representation of *age* modelled as categorical and continuous splined variables (on the log scale) is shown in Figure 19. Model 1, which defined age as a categorical variable, closely tracked the observed data. Model 2, which applied age as a linear splined variable with knots at 15, 30 and 60 years provided a model of comparable fit with age reduced from 17 to just 3 fitted parameters.

[18] As the coefficients in model 1 reflect categorical data, the constant corresponds to the estimated log mortality rate in the 0 to 4 year age category and the mortality rate in each subsequent age category is estimated by exponentiating the sum of this constant and the coefficient for that age category, e.g. estimated mortality rate in the 5 to 9 age category = exp (-9.94-0.84); 10 to 14 = exp (-9.94-0.26); etc. In model 2, however, the coefficients reflect changes in the log mortality rate for every 1 unit increase in age-category, where the categories are as indicated in model 1. Thus, the estimated mortality rate in the 5 to 9 age category = exp (-10.65 + 1.04); 10 to 14 = exp (-10.65 + 2*1.04); and, as there is a knot at 15 years, the mortality rate in the 15 to 19 = exp (-10.65 + 2*1.04 + 0.62); 20 to 24 = exp (-10.65 + 2*1.04 + 2*0.62), etc

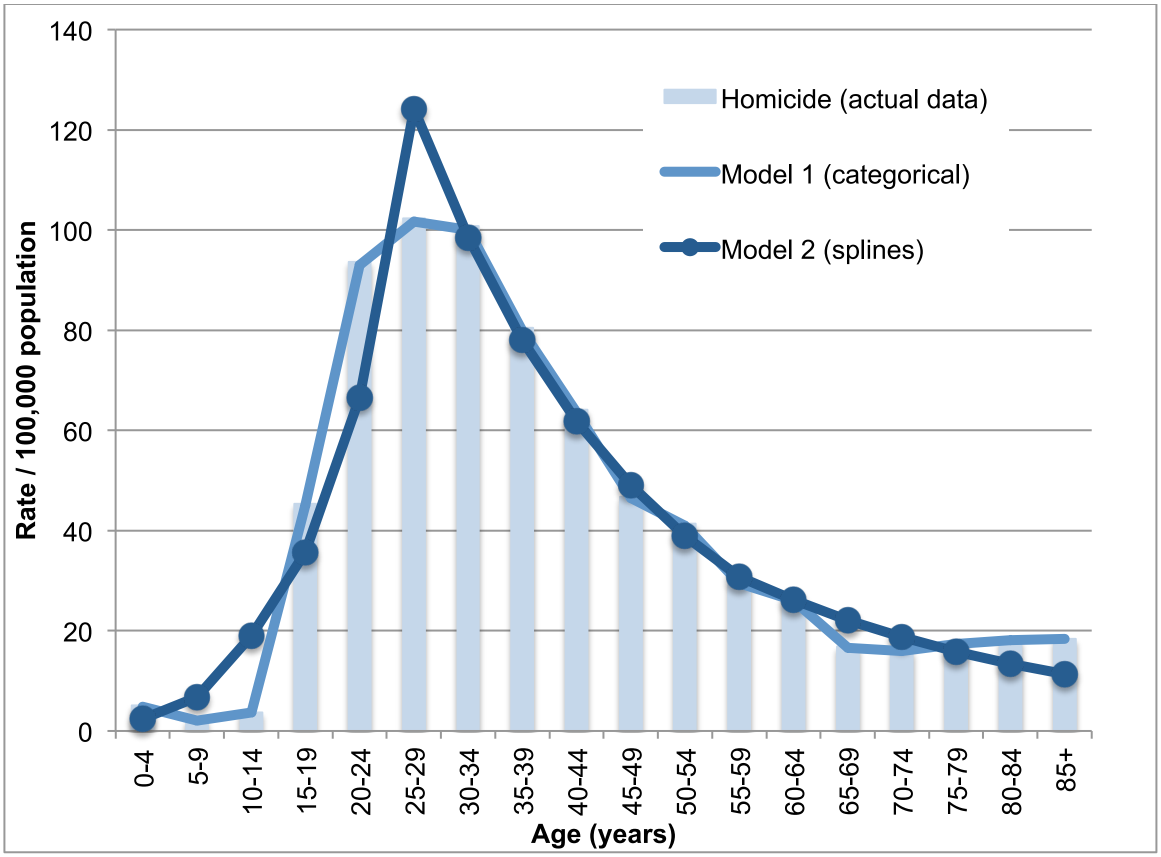

Figure 19. Age modelled as a continuous linear, categorical and continuous linear variable with splines

The corresponding categorical and splined models including imputed missing ages, as shown in Figure 15, had similar characteristics to the models utilising data with only known ages, i.e. with model 1 closely tracking the actual age-specific homicide rates and model 2 with splines at 15, 30 and 60 years reflecting higher rates in the younger age categories, but a sharper peak in the 25-29 year age category (Figure 20). Although rates derived from the data with only known ages underestimate the age-specific homicide rates due to a 10 percent proportion of cases with missing age data, it is only the data with known ages that will be utilised exclusively in the multivariable analyses that follows.

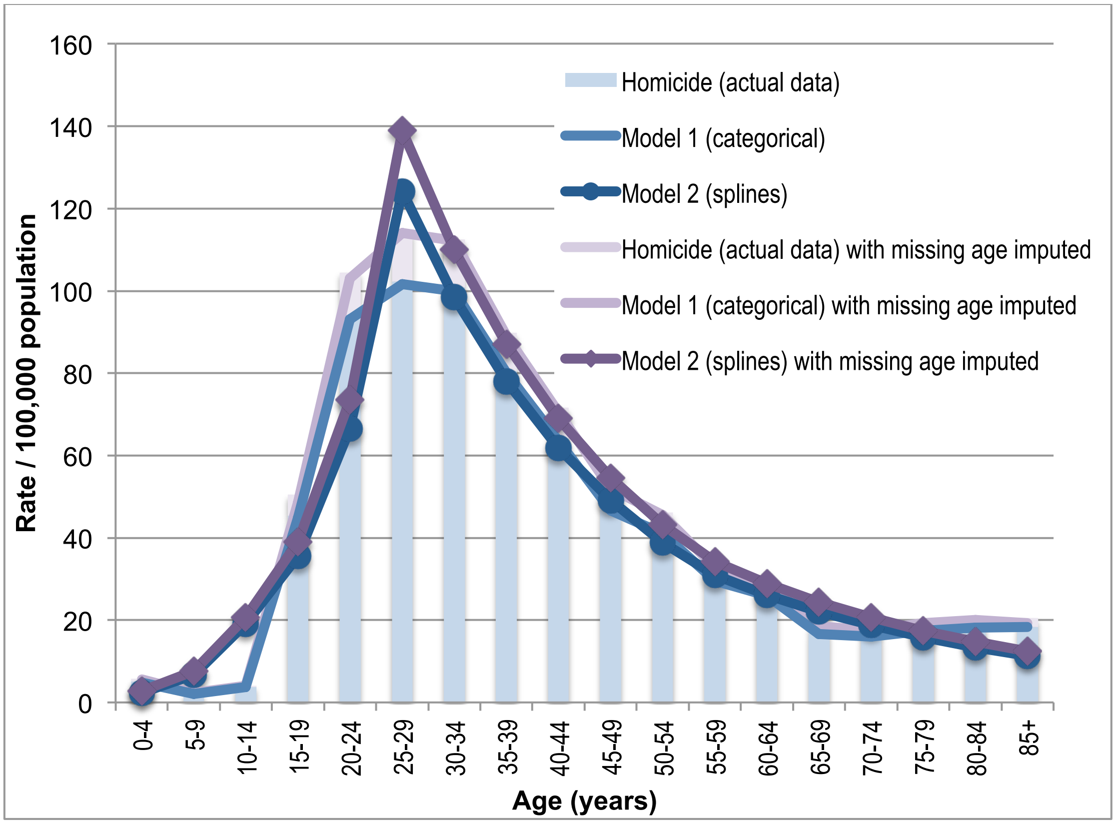

Figure 20. Age modelled as categorical and continuous linear variable with splines with missing age either omitted or imputed

The bivariate age-linear spline model (model 2) was used as a basis from which to investigate the role of *age* as a risk-factor for homicide. The specific aims were to identify potential confounders from among the other covariates and to test whether age was independently associated with homicide after taking into account the effect of other covariates: *sex*, *race*, *day of week*, *city* and *year of death*. The crude bivariate age-spline model (model 2) for homicide rate as a function of *age* demonstrated that the coefficients for each age spline were significant at the 5 percent level and that the inclusion of each additional covariate one at a time in trivariate models did not materially alter the magnitude of the coefficients for *age* (Table XIX). This indicated that the four linear spline relationships in the model were preserved and that *age* was an independent predictor of the homicide rate.

The trivariate analysis in Table XIX also showed that the inclusion of additional covariates, especially *sex*, *race* and *day of week* provided a better fit than the model with age alone (model 2 in Table XVIII), as well as showing that the effect of age on homicide could not be explained away by any single other variable. It was noteworthy that in all except the models with *city* (model 6) and *year of death* as covariates (model 7) the coefficients for each category of the covariate, adjusted for age, were significantly different from the baseline category at the 5 percent level. It should be noted that the p-values in the Tables for models 1, 5, 6 and 7 reflect comparisons for each category with the reference category and not those between adjacent categories, which are not necessarily different from one another.

In model 6 the baseline city, Cape Town, had a significantly higher homicide rate than Johannesburg and Pretoria when controlling for the effect of age. Although the estimated Cape Town homicide rate was also higher than in Durban and Port Elizabeth the difference was not statistically significant. In model 7, no significant changes were observed in homicide rates from 2001 (the baseline year) to 2003, but there was a significant decrease in 2004 and 2005. Despite the apparent non-linearity of this change in homicide rates, the decrease in 2004 and 2005 was so substantial as to reflect a significant result even when *year of death* was applied as a continuous variable (model 8). More detailed comparisons by each covariate are expounded further in the more complex modelling that follows.

Table XIX. Trivariate analysis showing the effect of each additional covariate on the crude homicide-by-age model

(Model no) covariates included	*Log likelihood*	*Dev.*	*Resid. df*	*AIC*	*BIC*
(1) *age* (categorical)	-36970	56832	25182	2.94	-198378
(2) *age* (continuous/splined) [crude model]	-38179	59248	25195	3.03	-196093
(3) *age* (continuous/splined), *sex* (categorical)	-27054	36998	25194	2.15	-218333

Parameter	Coefficient (95% CI)	P-val
Age (0-4). female [constant]	*-12.1 (-12.3:-11.9)*	*<0.01*
Age (5-14)	*1.05 (0.93:1.18)*	*<0.01*
Age (15-29)	*0.61 (0.57:0.66)*	*<0.01*
Age (30-59)	*-0.22 (-0.24:-0.20)*	*<0.01*
Age (60+)	*-0.13 (-0.16:-0.09)*	*<0.01*
Sex(male)	*2.02 (1.97:2.08)*	*<0.01*

(4) *age* (continuous/splined), *race* (categorical)	-35244	53378	25192	2.80	-201933
Parameter	Coefficient (95% CI)	P-val			
Age (0-4). African [constant]	*-10.5 (-10.68:-10.31)*	*<0.01*			
Age (5-14)	*1.07 (0.94:1.20)*	*<0.01*			
Age (15-29)	*0.61 (0.56:0.66)*	*<0.01*			
Age (30-59)	*-0.20 (-0.22:-0.18)*	*<0.01*			
Age (60+)	*-0.12 (-0.16:-0.08)*	*<0.01*			
Race (Asian)	*-1.22 (-1.32:-1.12)*	*<0.01*			
Race (Coloured)	*-0.21 (-0.31:-0.12)*	*<0.01*			
Race (White)	*-1.53 (-1.60:-1.45)*	*<0.01*			
(5) *age* (continuous/splined). *day of week* (categorical)	-35929	54751	25189	2.85	-200530
Parameter	Coefficient (95% CI)	P-val			
Age (0-4). Sunday [constant]	*-10.29 (-10.49:-10.08)*	*<0.01*			
Age (5-14)	*1.04 (0.91:1.17)*	*<0.01*			
Age (15-29)	*0.62 (0.57:0.67)*	*<0.01*			
Age (30-59)	*-0.23 (-0.25:-0.21)*	*<0.01*			
Age (60+)	*-0.17 (-0.21:-0.13)*	*<0.01*			
Monday	*-0.53 (-0.67:-0.38)*	*<0.01*			
Tuesday	*-0.72 (-0.87:-0.58)*	*<0.01*			
Wednesday	*-0.76 (-0.90:-0.62)*	*<0.01*			
Thursday	*-0.77 (-0.91:-0.63)*	*<0.01*			
Friday	*-0.38 (-0.52:-0.23)*	*<0.01*			
Saturday	*0.17 (0.020:0.32)*	*0.02*			
(6) *age* (continuous/splined), *city* (categorical)	-35808	54507	25191	2.84	-200793
Parameter	Coefficient (95% CI)	P-val			
Age (0-4). Cape Town [constant]	*-10.36 (-10.56:-10.16)*	*<0.01*			
Age (5-14)	*1.02 (0.89:1.15)*	*<0.01*			
Age (15-29)	*0.65 (0.60:0.70)*	*<0.01*			
Age (30-59)	*-0.24 (-0.26:-0.22)*	*<0.01*			
Age (60+)	*-0.17 (-0.21:-0.13)*	*<0.01*			
Durban	*-0.07 (-0.19:0.05)*	*0.25*			
Johannesburg	*-0.55 (-0.67:-0.44)*	*<0.01*			
Port Elizabeth	*-0.02 (-0.15:0.11)*	*0.75*			
Pretoria	*-1.25 (-1.37:-1.13)*	*<0.01*			
(7) *age* (continuous/splined), *year of death* (categorical)	-37999	58889	25191	3.02	-196411
Parameter	Coefficient (95% CI)	P-val			
Age (0-4). 2001 [constant]	*-10.55 (-10.75:-10.34)*	*<0.01*			
Age (5-14)	*1.04 (0.91:1.17)*	*<0.01*			
Age (15-29)	*0.62 (0.57:0.68)*	*<0.01*			
Age (30-59)	*-0.23 (-0.25:-0.21)*	*<0.01*			
Age (60+)	*-0.17 (-0.21:-0.13)*	*<0.01*			
2002	*0.03 (-0.10:0.16)*	*0.62*			
2003	*-0.11 (-0.24:0.02)*	*0.10*			
2004	*-0.21 (-0.34:-0.08)*	*<0.01*			
2005	*-0.22 (-0.36:-0.08)*	*<0.01*			
(8) *age* (continuous/splined), *year of death* (contin.)	-38025	58941	25194	3.02	-196390
Parameter	Coefficient (95% CI)	P-val			
Age (0-4). 2001 [constant]	*-10.44 (-10.65:-10.23)*	*<0.01*			
Age (5-14)	*1.04 (0.91:1.17)*	*<0.01*			
Age (15-29)	*0.62 (0.57:0.68)*	*<0.01*			
Age (30-59)	*-0.23 (-0.25:-0.21)*	*<0.01*			
Age (60+)	*-0.17 (-0.21:-0.13)*	*<0.01*			
Year	*-0.07 (-0.10:-0.04)*	*<0.01*			

Multivariable analyses summarised in Table XX, demonstrated that increasingly elaborate models in which other covariates of interest such as *sex*, *race* and *day of week* and *year of death* were added, provided a better fit than the simple models. This was evident in substantial decreases in both Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) with the inclusion of these covariates, particularly when *sex* and *race* were included. The multivariable analysis, as with the trivariate analysis in Table XIX, showed that *sex* followed by *race* were the most influential covariates in improving the overall fit of the bivariate age-spline model, followed by *city* and *day of* week, whereas *year of death* had the least influence. Consequently the full model with all covariates included (model 17) only had a marginally better fit than the full model without *year of death* (model 16).

Table XX. Multivariable analysis showing the improved fit from adding multiple covariates to the crude homicide-by-age model

(Model no) covariates included	*Log likelihood*	*Dev.*	*Resid. df*	*AIC*	*BIC*	*Total cov. incl.*
(2) *age* (continuous/splined) [crude model]	-38179	59248	25195	3.03	-196093	2
(9) age (continuous/splined), *sex* (categorical), race (categorical)	-24165	31221	25191	1.92	-224080	4
(10) age (continuous/splined), *sex* (categorical), *day of week* (categorical)	-24805	32501	25188	1.97	-222770	4
(11) age (continuous/splined), *sex* (categorical), *city* (categorical)	-24514	31918	25190	1.95	-223372	4
(12) age (continuous/splined), *sex* (categorical), *year* (categorical)	-26874	36638	25190	2.13	-218652	4
(13) age (continuous/splined), *sex* (categorical), *race* (categorical), *day of week* (categorical)	-21916	26723	25185	1.74	-228517	5
(14) age (continuous/splined), *sex* (categorical), race (categorical), *city* (categorical)	-21026	24944	25187	1.67	-230317	5
(15) age (continuous/splined), *sex* (categorical), race (categorical), *year* (categorical)	-23970	30832	25187	1.90	-224429	5
(16) age (continuous/splined), *sex* (categorical), *race* (categorical), *day of week* (categorical), *city* (categorical)	-18777	20446	25181	1.49	-234753	6
(17) age (continuous/splined), *sex* (categorical), *race* (categorical), *day of week* (categorical), *city* (categorical), year (categorical)	-18577	20044	25177	1.48	-235115	7

Inspection of the coefficients across the various models (in Tables XXI through Table XXIV) indicated one noteworthy and consistent change in the older (60+) age category with the introduction of *race* alongside *sex*, which suggested some confounding, i.e. when race and sex were adjusted for there was a different effect for those age>60. For example, in model 9 (Table XXI) the inclusion of *race* as a categorical variable alongside *age* and *sex* improved overall fit (see Table XX in which there were substantial decreases in both AIC and BIC compared to model 2). However, the magnitude of effect for age > 60 years was considerably smaller in model 9 (Table XXI) with the inclusion of *race* and *sex* together than with *race* or *sex* alone, for which the coefficient for age > 60 was essentially unchanged (Table XIX).

Table XXI. The effect of adding race and sex to the homicide-by-age model

(Model no) covariates included		
(9) *age* (continuous/splined), *sex* (categorical), *race* (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, African [constant]	*-11.95 (-12.16:-11.75)*	*<0.01*
Age (5-14)	*1.08 (0.96:1.21)*	*<0.01*
Age (15-29)	*0.60 (0.55:0.64)*	*<0.01*
Age (30-59)	*-0.18 (-0.20:-0.17)*	*<0.01*
Age (60+)	*-0.07 (-0.11:-0.04)*	*<0.01*
Sex(male)	*2.02 (1.96:2.07)*	*<0.01*
Race (Asian)	*-1.21 (-1.29:-1.13)*	*<0.01*
Race (Coloured)	*-0.18 (-0.25:-0.11)*	*<0.01*
Race (White)	*-1.52 (-1.59:-1.45)*	*<0.01*

In model 10, the inclusion of *day of week* as a categorical variable alongside *age* and *sex* improved the model fit considerably with all covariates remaining significant at the 5 percent level. The inclusion of *day of week* and *race* alongside *age* and *sex* (model 13) improved the fit of the model even further but, again, the same moderate confounding effect was observed for age older than 60 years with the inclusion of *race* and *sex* (Table XXII).

Table XXII. The effect of adding day of week, race and sex to the homicide-by-age model

(Model no) covariates included		
(10) *age* (continuous/splined), *sex* (categorical), *day of week* (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, Sunday [constant]	*-11.74 (-11.95:-11.53)*	*<0.01*
Age (5-14)	*1.05 (0.93:1.17)*	*<0.01*
Age (15-29)	*0.61 (0.57:0.65)*	*<0.01*
Age (30-59)	*-0.22 (-0.24:-0.20)*	*<0.01*
Age (60+)	*-0.13 (-0.16:-0.09)*	*<0.01*
Sex(male)	*2.02 (1.97:2.07)*	*<0.01*
Monday	*-0.53 (-0.63:-0.42)*	*<0.01*
Tuesday	*-0.72 (-0.83:-0.62)*	*<0.01*
Wednesday	*-0.76 (-0.86:-0.65)*	*<0.01*
Thursday	*-0.77 (-0.88:-0.66)*	*<0.01*
Friday	*-0.38 (-0.49:-0.27)*	*<0.01*
Saturday	*0.17 (0.06:0.29)*	*<0.01*
(13) age (continuous/splined), sex (categorical), day of week (categorical) race (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, Sunday, African [constant]	*-11.59 (-11.81:-11.38)*	*<0.01*
Age (5-14)	*1.08 (0.96:1.21)*	*<0.01*
Age (15-29)	*0.60 (0.56:0.64)*	*<0.01*
Age (30-59)	*-0.18 (-0.20:-0.17)*	*<0.01*
Age (60+)	*-0.07 (-0.11:-0.04)*	*<0.01*
Sex(male)	*2.02 (1.97:2.07)*	*<0.01*
Race (Asian)	*-1.21 (-1.29:-1.13)*	*<0.01*
Race (Coloured)	*-0.18 (-0.24:-0.12)*	*<0.01*
Race (White)	*-1.52 (-1.59:-1.45)*	*<0.01*
Monday	*-0.53 (-0.63:-0.42)*	*<0.01*
Tuesday	*-0.72 (-0.83:-0.62)*	*<0.01*
Wednesday	*-0.76 (-0.86:-0.65)*	*<0.01*
Thursday	*-0.77 (-0.87:-0.66)*	*<0.01*
Friday	*-0.38 (-0.49:-0.27)*	*<0.01*
Saturday	*0.17 (0.06:0.28)*	*<0.01*

For model 11, the inclusion of *sex* and *city* alongside *age* as covariates for homicide, had negligible effect on the age spline covariates. Johannesburg and Pretoria again had significantly lower homicide rates than Cape Town (Table XXIII). The inclusion of *race* (model 14) also indicated that every other city had significantly lower homicide rates than Cape Town among people of the same *age*, *race* and *sex*, and also that there were significant differences among the other cities. Whereas Durban and Port Elizabeth were similar, the homicide rates in these two cities were significantly higher than Johannesburg, which in turn had significantly higher homicide rates than Pretoria.

Among people of the same *age*, *race* and *sex* Cape Town had the highest homicide rates followed by Durban, Port Elizabeth, Johannesburg and then Pretoria. In addition, the inclusion of *race* and *sex* had a marked effect on the value of the coefficient for the older (60+) age categories as was also the case in the model 9 (Table XXI). However, *w*hen *race* only or *sex* only were included in the model there was a negligible impact on the coefficient for age greater than 60 years, suggesting that *race* and *sex* might jointly confound the association of age greater than 60 years with homicide. This effect was observed in model 14 and was consistent across (model 17) as well as the full model without *year of death* (model 16) – see Table XXV. The effect of *race* on homicide by *age* model and the effect of *race* on homicide by *sex* will be explored in greater detail in sections 6.3.3 and 6.3.4

Table XXIII. The effect of adding *city*, *race* and *sex* to the homicide-by-age model

(Model no) covariates included		
(11) *age* (continuous/splined), *sex* (categorical), *city* (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, Cape Town [constant]	*-11.82 (-12.02:-11.62)*	*<0.01*
Age (5-14)	*1.03 (0.91:1.15)*	*<0.01*
Age (15-29)	*0.64 (0.60:0.68)*	*<0.01*
Age (30-59)	*-0.23 (-0.24:-0.21)*	*<0.01*
Age (60+)	*-0.13 (-0.17:-0.09)*	*<0.01*
Sex(male)	*2.03 (1.98:2.09)*	*<0.01*
Durban	*-0.08 (-0.17:0.01)*	*0.10*
Johannesburg	*-0.60 (-0.68:-0.51)*	*<0.01*
Port Elizabeth	*-0.02 (-0.12:0.09)*	*0.73*
Pretoria	*-1.27 (-1.37:-1.18)*	*<0.01*
(14) *age* (continuous/splined), *sex* (categorical), race (categorical), *city* (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age(0-4), female, African, Cape Town [constant]	*-11.44 (-11.65:-11.23)*	*<0.01*
Age (5-14)	*1.07 (0.94:1.19)*	*<0.01*
Age (15-29)	*0.62 (0.58:0.65)*	*<0.01*
Age (30-59)	*-0.18 (-0.20:-0.17)*	*<0.01*
Age (60+)	*-0.08 (-0.11:-0.04)*	*<0.01*
Sex(male)	*2.03 (1.98:2.08)*	*<0.01*
Race (Asian)	*-1.40 (-1.48:-1.31)*	*<0.01*
Race (Coloured)	*-0.61 (-0.70:-0.52)*	*<0.01*
Race (White)	*-1.58 (-1.65:-1.50)*	*<0.01*
Durban	*-0.26 (-0.35:-0.16)*	*<0.01*
Johannesburg	*-0.85 (-0.94:-0.75)*	*<0.01*
Port Elizabeth	*-0.19 (-0.30:-0.08)*	*<0.01*
Pretoria	*-1.49 (-1.60:-1.39)*	*<0.01*

The only other noteworthy change observed with the introduction of additional covariates was in model 12 with the inclusion of *sex* alongside *age* and *year of death* (Table XXIV).

This had a negligible effect on the age spline covariates and so confounding was not evident, although there was a change in the year in which the significant decrease in homicide compared with baseline was evident, i.e. in 2003 rather than in 2004 (as shown in model 7, Table XIX). This was also consistent with the change point observed in the full model with all covariates included (model 17) – see Table XXV.

Table XXIV. The effect of adding year of death and sex to the homicide-by-age model

(Model no) covariates included		
(12) *age* (continuous/splined), *sex* (categorical), *year of death* (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, 2001 [constant]	*-12 (-12.22:-11.79)*	*<0.01*
Age (5-14)	*1.05 (0.93:1.18)*	*<0.01*
Age (15-29)	*0.62 (0.57:0.66)*	*<0.01*
Age (30-59)	*-0.22 (-0.24:-0.2)*	*<0.01*
Age (60+)	*-0.13 (-0.16:-0.09)*	*<0.01*
Sex(male)	*2.02 (1.97:2.08)*	*<0.01*
2002	*0.03 (-0.07:0.13)*	*0.51*
2003	*-0.11 (-0.21:-0.01)*	*0.04*
2004	*-0.21 (-0.31:-0.11)*	*<0.01*
2005	*-0.22 (-0.34:-0.11)*	*<0.01*

Other than these rather moderate effects it was clear that the inclusion of additional variables had little bearing on the age coefficients that underpin the age-homicide rate relationship (Table XXV). This suggests that this association was not an artifact of confounders such as *race* and *city* that have both different homicide rates and different age distributions.

Table XXV. The effect of more elaborate models on homicide-by-age

(Model no) covariates included		
(16) *age* (continuous/splined), *sex* (categorical), *race* (categorical), *city* (categorical), *day of week* (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, African, Cape Town, Sunday [constant]	*-11.08 (-11.30:-10.87)*	*<0.01*
Age (5-14)	*1.07 (0.95:1.19)*	*<0.01*
Age (15-29)	*0.62 (0.58:0.65)*	*<0.01*
Age (30-59)	*-0.18 (-0.19:-0.17)*	*<0.01*
Age (60+)	*-0.08 (-0.11:-0.05)*	*<0.01*
Sex (male)	*2.03 (1.99:2.07)*	*<0.01*
Race (Asian)	*-1.40 (-1.48:-1.32)*	*<0.01*
Race (Coloured)	*-0.61 (-0.67:-0.54)*	*<0.01*
Race (White)	*-1.58 (-1.65:-1.51)*	*<0.01*
Durban	*-0.53 (-0.60:-0.45)*	*<0.01*
Johannesburg	*-0.72 (-0.80:-0.65)*	*<0.01*
Port Elizabeth	*-0.76 (-0.83:-0.68)*	*<0.01*
Pretoria	*-0.77 (-0.84:-0.69)*	*<0.01*
Monday	*-0.38 (-0.45:-0.31)*	*<0.01*
Tuesday	*0.17 (0.10:0.24)*	*<0.01*
Wednesday	*-0.26 (-0.32:-0.19)*	*<0.01*
Thursday	*-0.85 (-0.92:-0.78)*	*<0.01*
Friday	*-0.19 (-0.27:-0.11)*	*<0.01*
Saturday	*-1.49 (-1.57:-1.41)*	*<0.01*
(17) *age* (continuous/splined), *sex* (categorical), *race* (categorical), *city* (categorical), *day of week* (categorical), *year of death* (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, African, Sunday, Cape Town, 2001 [constant]	*-10.97 (-11.19:-10.76)*	*<0.01*
Age (5-14)	*1.07 (0.95:1.18)*	*<0.01*
Age (15-29)	*0.62 (0.58:0.65)*	*<0.01*
Age (30-59)	*-0.18 (-0.19:-0.17)*	*<0.01*
Age (60+)	*-0.08 (-0.11:-0.05)*	*<0.01*
Sex(male)	*2.03 (1.99:2.07)*	*<0.01*
Race (Asian)	*-1.4 (-1.48:-1.32)*	*<0.01*
Race (Coloured)	*-0.61 (-0.67:-0.54)*	*<0.01*
Race (White)	*-1.58 (-1.65:-1.51)*	*<0.01*
Monday	*-0.53 (-0.60:-0.46)*	*<0.01*
Tuesday	*-0.72 (-0.80:-0.65)*	*<0.01*
Wednesday	*-0.76 (-0.83:-0.69)*	*<0.01*
Thursday	*-0.77 (-0.84:-0.7)*	*<0.01*
Friday	*-0.38 (-0.45:-0.31)*	*<0.01*
Saturday	*0.17 (0.10:0.24)*	*<0.01*
Durban	*-0.26 (-0.33:-0.19)*	*<0.01*
Johannesburg	*-0.85 (-0.92:-0.78)*	*<0.01*
Port Elizabeth	*-0.19 (-0.27:-0.11)*	*<0.01*
Pretoria	*-1.49 (-1.57:-1.41)*	*<0.01*
2002	*0.03 (-0.03:0.08)*	*0.31*
2003	*-0.12 (-0.17:-0.06)*	*<0.01*
2004	*-0.22 (-0.28:-0.16)*	*<0.01*
2005	*-0.24 (-0.31:-0.17)*	*<0.01*

As regards any possible effects of the missing age values on the final model, the analysis described in Appendix IV suggest that these would not have materially affected the estimated coefficients based on the data set excluding deaths with missing ages and thus did not have a differential effect on the estimated associations in the final model. To demonstrate the extent of the effect on the current modelling, the regression analysis for the full model was applied to a data set (model 18 in Table XXVI) with missing age values imputed as shown in Figure N. This sensitivity analysis showed that the effects were negligible, with the current analysis based on only data with known ages only marginally underestimating the point estimates for fatality rates overall. However, it should be noted that reliance on this single imputation does not allow for adjusted (for the imputation) standard errors to be calculated for these point estimates. Although single imputation provides an optimistic estimate of the standard errors (SEs) the small p-values of the coefficients suggests that the impact of a small adjustment in the SEs would not result in a substantially different p-value to the extent of altering conclusions as to statistical significance.

Table XXVI. Application of the full model to a revised data set with missing values imputed

(Model no) covariates included		
(18) *age* (continuous/splined), *sex* (categorical), *race* (categorical), *city* (categorical), *day of week* (categorical), *year of death* (categorical)		
Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, African, Sunday, Cape Town, 2001 [constant]	-10.82 (-11.04:-10.61)	*<0.01*
Age (5-14)	1.03 (0.92:1.15)	*<0.01*
Age (15-29)	0.62 (0.59:0.65)	*<0.01*
Age (30-59)	-0.18 (-0.19:-0.17)	*<0.01*
Age (60+)	-0.08 (-0.11:-0.05)	*<0.01*
Sex(male)	2.03 (1.99:2.07)	*<0.01*
Race (Asian)	-1.42 (-1.50:-1.34)	*<0.01*
Race (Coloured)	-0.61 (-0.67:-0.54)	*<0.01*
Race (White)	-1.60 (-1.67:-1.53)	*<0.01*
Monday	-0.51 (-0.58:-0.44)	*<0.01*
Tuesday	-0.72 (-0.79:-0.65)	*<0.01*
Wednesday	-0.75 (-0.82:-0.68)	*<0.01*
Thursday	-0.77 (-0.84:-0.70)	*<0.01*
Friday	-0.39 (-0.46:-0.32)	*<0.01*
Saturday	0.17 (0.10:0.24)	*<0.01*
Durban	-0.30 (-0.37:-0.24)	*<0.01*
Johannesburg	-0.66 (-0.72:-0.59)	*<0.01*
Port Elizabeth	-0.18 (-0.26:-0.10)	*<0.01*
Pretoria	-1.26 (-1.33:-1.18)	*<0.01*
2002	-0.01 (-0.07:0.04)	0.63
2003	-0.15 (-0.20:-0.09)	*<0.01*
2004	-0.29 (-0.35:-0.23)	*<0.01*
2005	-0.31 (-0.37:-0.24)	*<0.01*

So in summary the multivariable analysis of a simplified homicide-age model with three linear splines with knots at 15, 30 and 60 years showed that homicide rates increased rapidly from 15 to 29 years, dropped rapidly from 30 to 60 years and then decreased marginally thereafter. Furthermore, the analysis suggested that age differentials visible in the unadjusted graphical analysis of homicide rates were real and did not represent confounding by the other covariates such as *sex*, *race*, *city* , *year of death* or *day of week*. In terms of these variables' influence on the multivariable model, *sex* had the greatest effect in improving overall fit, followed by *race*, *city*, *day of week*, and *year of death*, based on the resultant reduction in AIC and BIC values when the respective variables were included in the models.

This analysis fully satisfies *Hypothesis 1* and its six sub-hypotheses in that *age*, *sex*, *race*, *city*, *year of death* and *day of week* were shown to be independent predictors of homicide.The full model showed that, in addition to *age*, each of the covariates had a significant effect on homicide rates. Pairwise baseline and non-baseline comparisons for the covariates are summarised in Table XXVII.

Table XXVII. Pairwise baseline and non-baseline comparisons for each covariate

	IRR (95% C.I)	Inverse IRR (95% C.I)
Sex		
**Female vs. male*	0.13 (0.13; 0.14)	7.62 (7.31; 7.95)
Race		
**Asian vs. African*	0.25 (0.23; 0.27)	4.06 (3.74; 4.40)
**Coloured vs. African*	0.54 (0.51; 0.58)	1.84 (1.72; 1.96)
**White vs. African*	0.21 (0.19; 0.22)	4.86 (4.53; 5.21)
*Coloured *vs. Asian*	2.21 (2.00; 2.44)	0.45 (0.41; 0.50)
*White *vs. Asian*	0.84 (0.75; 0.93)	1.20 (1.08; 1.33)
*White vs. Coloured	0.38 (0.35; 0.41)	2.64 (2.44; 2.86)
City		
**Durban vs. Cape Town*	0.77 (0.72; 0.83)	1.29 (1.21; 1.39)
**Johannesburg vs. Cape Town*	0.43 (0.40; 0.46)	2.34 (2.19; 2.51)
**Port Elizabeth vs. Cape Town*	0.83 (0.76; 0.89)	1.21 (1.12; 1.31)
**Pretoria vs. Cape Town*	0.22 (0.21; 0.24)	4.46 (4.11; 4.83)
**Johannesburg vs. Durban*	0.55 (0.53; 0.58)	1.81 (1.73; 1.90)
Port Elizabeth vs. Durban	1.07 (1.00; 1.14)	0.94 (0.87; 1.00)

**Pretoria vs. Durban*	0.29 (0.27; 0.31)	3.44 (3.23; 3.66)
**Port Elizabeth vs. Johannesburg*	1.93 (1.80; 2.07)	0.52 (0.48; 0.55)
**Pretoria vs. Johannesburg*	0.53 (0.49; 0.56)	1.90 (1.78; 2.03)
**Pretoria vs. Port Elizabeth*	0.27 (0.25; 0.29)	3.68 (3.39; 3.98)
Day of week		
**Monday vs. Sunday*	0.59 (0.55; 0.63)	1.69 (1.58; 1.81)
**Tuesday vs. Sunday*	0.48 (0.45; 0.52)	2.06 (1.92; 2.21)
**Wednesday vs. Sunday*	0.47 (0.44; 0.5)	2.14 (1.99; 2.29)
**Thursday vs. Sunday*	0.46 (0.43; 0.5)	2.16 (2.01; 2.32)
**Friday vs. Sunday*	0.69 (0.64; 0.74)	1.46 (1.36; 1.57)
**Saturday vs. Sunday*	1.19 (1.11; 1.28)	0.84 (0.78; 0.9)
**Tuesday vs. Monday*	0.82 (0.77; 0.88)	1.22 (1.14; 1.3)
**Wednesday vs. Monday*	0.79 (0.74; 0.85)	1.26 (1.18; 1.35)
**Thursday vs. Monday*	0.79 (0.73; 0.84)	1.27 (1.19; 1.36)
**Friday vs. Monday*	1.16 (1.09; 1.24)	0.86 (0.81; 0.92)
**Saturday vs. Monday*	2.01 (1.89; 2.15)	0.5 (0.46; 0.53)
Wednesday vs. Tuesday	0.97 (0.9; 1.04)	1.04 (0.97; 1.11)
Thursday vs. Tuesday	0.96 (0.89; 1.03)	1.05 (0.97; 1.12)
**Friday vs. Tuesday*	1.41 (1.32; 1.51)	0.71 (0.66; 0.76)
**Saturday vs. Tuesday*	2.45 (2.29; 2.63)	0.41 (0.38; 0.44)
Thursday vs. Wednesday	0.99 (0.92; 1.06)	1.01 (0.94; 1.08)
**Friday vs.Wednesday*	1.46 (1.37; 1.57)	0.68 (0.64; 0.73)
**Saturday vs. Wednesday*	2.54 (2.37; 2.72)	0.39 (0.37; 0.42)
**Friday vs. Thursday*	1.48 (1.38; 1.59)	0.68 (0.63; 0.73)
**Saturday vs. Thursday*	2.57 (2.39; 2.75)	0.39 (0.36; 0.42)
**Saturday vs. Friday*	1.74 (1.62; 1.86)	0.58 (0.54; 0.62)
Year of death		
2001 vs. 2002	1.03 (0.97; 1.09)	0.97 (0.92; 1.03)
**2002 vs. 2003*	0.86 (0.81; 0.92)	1.16 (1.09; 1.23)
**2003 vs. 2004*	0.9 (0.85; 0.96)	1.11 (1.04; 1.18)
2004 vs. 2005	0.98 (0.91; 1.06)	1.02 (0.95; 1.09)

* Denotes statistical significance at the 5 percent level.

In summary:

- for *sex*, males were at significantly higher risk than females;
- for *race*, Africans were at significantly higher risk than Coloureds. Coloureds were at significantly higher risk than Asians, who were at significantly higher risk than Whites;
- for *city*, Cape Town had a significantly higher homicide rate than Port Elizabeth and Durban, which had significantly higher rate than Johannesburg, which had a significantly higher rate than Pretoria;

- for *day of week*, each day was associated with significantly lower risk than Sunday except Saturday. In terms of the relative homicide risk the ranking was as follows: Saturday > Sunday > Friday > Monday > Tuesday, Wednesday and Thursday. Differences were significant at the 5 percent level except for the three midweek days (Tuesday, Wednesday and Thursday);
- for *year of death* there appeared to have been a significant decrease in homicide rates from 2002 to 2003. There was another significant decrease from 2003 to 2004 and although there was a further decrease from 2004 to 2005 the decrease was not significant.

6.3.2. *City* modifying the effect of *race* (Hypothesis 2.1)

In order to assess whether the effect of *race* on homicide rates was homogenous across cities an interaction term for *race* and *city* was included in a revised final, model 19 (Table XXVIII).

Table XXVIII. The effect of *race* on homicide by *city*

(Model no) covariates included	*Log likeli*	*Dev.*	*Resid. df*	*AIC*	*BIC*
(19) *age* (cont./splined), *sex*, *race*, *day of week*, *year of death* (cat.)	-18233	19357	25165	1.45	-235679

Parameter	Coefficient (95% CI)	P-val
Age (0-4, female. African, Cape Town, Sunday, 2001 [constant]	-10.89 (-11.11:-10.68)	<0.01
Age (5-14)	1.07 (0.95:1.19)	<0.01
Age (15-29)	0.61 (0.58:0.65)	<0.01
Age (30-59)	-0.18 (-0.19:-0.17)	<0.01
Age (60+)	-0.07 (-0.11:-0.04)	<0.01
Sex(male)	2.03 (1.99:2.07)	<0.01
Race (Asian)[a]	-2.40 (-2.83:-1.97)	<0.01
Race (Coloured)	-0.76 (-0.84:-0.68)	<0.01
Race (White)	-2.16 (-2.29:-2.03)	<0.01
Monday	-0.53 (-0.59:-0.46)	<0.01
Tuesday	-0.72 (-0.80:-0.65)	<0.01
Wednesday	-0.76 (-0.83:-0.69)	<0.01
Thursday	-0.77 (-0.84:-0.70)	<0.01
Friday	-0.38 (-0.45:-0.31)	<0.01
Saturday	0.17 (0.11:0.24)	<0.01
Durban[b]	-0.33 (-0.40:-0.26)	<0.01
Johannesburg	-0.99 (-1.06:-0.91)	<0.01
Port Elizabeth	-0.32 (-0.42:-0.22)	<0.01
Pretoria	-1.67 (-1.76:-1.59)	<0.01
2002	0.03 (-0.03:0.08)	0.32
2003	-0.12 (-0.17:-0.06)	<0.01
2004	-0.22 (-0.28:-0.17)	<0.01
2005	-0.24 (-0.31:-0.17)	<0.01
Asians, Durban[c]	0.94 (0.50:1.38)	<0.01
Asians, Johannesburg	1.53 (1.07:2.00)	<0.01
Asians, Port Elizabeth	1.17 (0.49:1.85)	<0.01
Asians, Pretoria	1.61 (0.98:2.24)	<0.01
Coloureds, Durban	-0.04 (-0.21:0.13)	0.65
Coloureds, Johannesburg	0.39 (0.24:0.53)	<0.01
Coloureds, Port Elizabeth	0.46 (0.32:0.61)	<0.01
Coloureds, Pretoria	1.35 (1.11:1.60)	<0.01
Whites, Durban	0.32 (0.11:0.53)	<0.01
Whites, Johannesburg	1.28 (1.11:1.45)	<0.01
Whites, Port Elizabeth	0.05 (-0.21:0.31)	0.73
Whites, Pretoria	1.35 (1.15:1.55)	<0.01

a. This is the effect of *race* (relative to Africans) in Cape Town for a given *sex*, *year*; b. This is the effect of *city* (relative to Cape Town) for Africans for a given *sex*, *year*; c. This reflects the extent to which rates for Asians in Durban versus Cape Town are different from Africans in Durban versus Cape Town (or, equivalently, the extent to which rates for Asians versus Africans in Durban are different from Asians vs Africans in Cape Town).

As well as further improving the fit of the final model, incidence rate ratios derived from model 19 revealed considerable differences in homicide risk across cities when stratified by race, most of the incidence rate ratios (IRRs) statistically significant at the 5 percent level[19]. Most notably, the homicide risk in Cape Town was significantly higher for Africans than in any other city. Similarly, Coloureds were also at significantly higher risk in Cape Town than in Durban, Johannesburg and Pretoria, although Coloureds residing in Port Elizabeth were at a significantly higher risk than in Cape Town (Table XXIX). In contrast, Cape Town was significantly safer for Asians than Durban, Johannesburg and Port Elizabeth, which was the most dangerous city for Asians as well as Coloureds. Johannesburg was the most dangerous city for whites, who were at significantly higher risk than in Cape Town.

Table XXIX. Relative risk of homicide by *city* and *race*

	IRR (95% C.I)	Inverse IRR (95% C.I)
Africans		
** Durban vs. Cape Town*	0.72 (0.67; 0.77)	1.39 (1.29; 1.50)
** Johannesburg vs. Cape Town*	0.37 (0.35; 0.40)	2.68 (2.49; 2.89)
** Port Elizabeth vs. Cape Town*	0.73 (0.66; 0.80)	1.38 (1.25; 1.52)
** Pretoria vs. Cape Town*	0.19 (0.17; 0.20)	5.32 (4.88; 5.80)
Asians		
**Durban vs. Cape Town*	1.84 (1.19; 2.85)	0.54 (0.35; 0.84)
**Johannesburg vs. Cape Town*	1.73 (1.09; 2.73)	0.58 (0.37; 0.92)
**Port Elizabeth vs. Cape Town*	2.34 (1.20; 4.58)	0.43 (0.22; 0.83)
Pretoria vs. Cape Town	0.94 (0.51; 1.75)	1.06 (0.57; 1.98)
Coloureds		
**Durban vs. Cape Town*	0.69 (0.59; 0.81)	1.45 (1.24; 1.70)
**Johannesburg vs. Cape Town*	0.55 (0.48; 0.62)	1.82 (1.61; 2.06)
**Port Elizabeth vs. Cape Town*	1.15 (1.04; 1.28)	0.87 (0.78; 0.96)
**Pretoria vs. Cape Town*	0.73 (0.58; 0.91)	1.37 (1.09; 1.73)
Whites		
Durban vs. Cape Town	0.99 (0.81; 1.20)	1.01 (0.83; 1.23)
**Johannesburg vs. Cape Town*	1.34 (1.14; 1.57)	0.75 (0.64; 0.87)
**Port Elizabeth vs. Cape Town*	0.76 (0.60; 0.97)	1.31 (1.03; 1.68)
**Pretoria vs. Cape Town*	0.72 (0.60; 0.87)	1.38 (1.15; 1.66)

* Denotes statistical significance at the 5 percent level.

[19] All incidence rate ratios (IRRs) were adjusted for all other covariates and hence reflect the relative probability of homicide risk in different cities between people of the same *race*.

Table XXIX also indicated that whereas Africans in Cape Town were at significantly higher risk than in many other cities, Asians and Coloureds experienced the highest homicide risk in Port Elizabeth and Whites in Johannesburg. The relative risk and the risk ranking for each city by race is shown in Table XXX. Using the highest risk city as the basis for comparison, this analysis also revealed that these highest risk cities were significantly riskier than the other cities for individual race groups (Table XXX). So, not only was the risk of homicide in Cape Town for Africans significantly higher than for any other city, but Coloureds and Asians in Port Elizabeth and Whites in Johannesburg were at significantly higher risk than in any other city[20].

Table XXX. Highest risk city for each race

	IRR (95% C.I)	Rank
Africans – Cape Town		1
* *vs. Durban*	1.39 (1.29; 1.50)	3
* *vs. Johannesburg*	2.68 (2.49; 2.89)	4
* *vs. Port Elizabeth*	1.38 (1.25; 1.52)	2
* *vs. Pretoria*	5.32 (4.88; 5.80)	5
Asians-Port Elizabeth		1
vs. Cape Town	2.34 (1.20; 4.58)	4
vs. Durban	1.27 (0.75; 2.15)	2
vs. Johannesburg	1.36 (0.79; 2.34)	3
vs. Pretoria	2.49 (1.25; 4.95)	5
Coloureds – Port Elizabeth		1
* *vs. Cape Town*	1.15 (1.04; 1.28)	2
* *vs. Durban*	1.67 (1.41; 1.99)	4
* *vs. Johannesburg*	2.10 (1.82; 2.43)	5
* *vs. Pretoria*	1.59 (1.25; 2.02)	3
Whites – Johannesburg		1
* *vs. Cape Town*	1.34 (1.14; 1.57)	2
* *vs. Durban*	1.36 (1.12; 1.64)	3
* *vs. Port Elizabeth*	1.76 (1.39; 2.24)	4
* *vs. Pretoria*	1.85 (1.55; 2.21)	5

* Denotes statistical significance at the 5 percent level.

The differences by *race* were consistent across all cities. Summarising the risk for each *race* from Table XXX:

[20] The IRRs in this table were again adjusted for all other covariates and reflect the relative risk of homicide risk among people of the same *race*. However, for each race the baseline city was chosen to be the highest risk city for that race. So, for example, Asians in Port Elizabeth (the highest risk city) were 36 percent more likely to be killed than in Johannesburg and almost two and a half times more likely to be killed than in Pretoria.

- *Africans* residing in Cape Town were at significantly higher risk of homicide than *Africans* residing in Durban and Port Elizabeth who, in turn were at significantly higher risk than *Africans* residing in Johannesburg, who, in turn were at significantly higher risk than *Africans* residing in Pretoria;
- *Asians* residing in Port Elizabeth, Durban and Johannesburg were at significantly higher risk of homicide than *Asians* residing in Cape Town and Pretoria;
- *Coloureds* residing in Port Elizabeth were at significantly higher risk of homicide than *Coloureds* residing in the other four cities. *Coloureds* residing in Cape Town were at significantly higher risk than *Coloureds* residing in Durban and Johannesburg, but were not at significantly higher risk than *Coloureds* residing in Pretoria;
- *Whites* residing in Johannesburg were at significantly higher risk of homicide than *Whites* residing in the other four cities.

The relatively higher risk among historically more disadvantaged groups in Cape Town and Port Elizabeth suggest that there may be higher levels of inequality in these cities. As regards the significantly higher homicide risk among whites in Johannesburg, this was consistent with the explanation that homicide risk among Whites is a major driver of perceptions of city safety as reflected in the Victims of Crime Survey.

6.3.3. The effect of *race* on homicide by *age* (Hypothesis 2.2)

The homicide rates by *age* and *race* derived from the full model (model 17) and adjusting for all the other covariates is represented graphically in Figure 21[21]. In summary, the full model presents both *race* and *age* as independent predictors of homicide or, alternatively, *race* as a confounder of the age-homicide relationship (or, similarly, *age* as a confounder of the race-homicide relationship).

[21] This chart shows the age-homicide relationship by race for a single sub-group, in this case the baseline category: females in Cape Town on a Sunday in 2001. Changing any of the reference categories would change the magnitude of the homicide rates, but not the shape of the curves relative to one another.

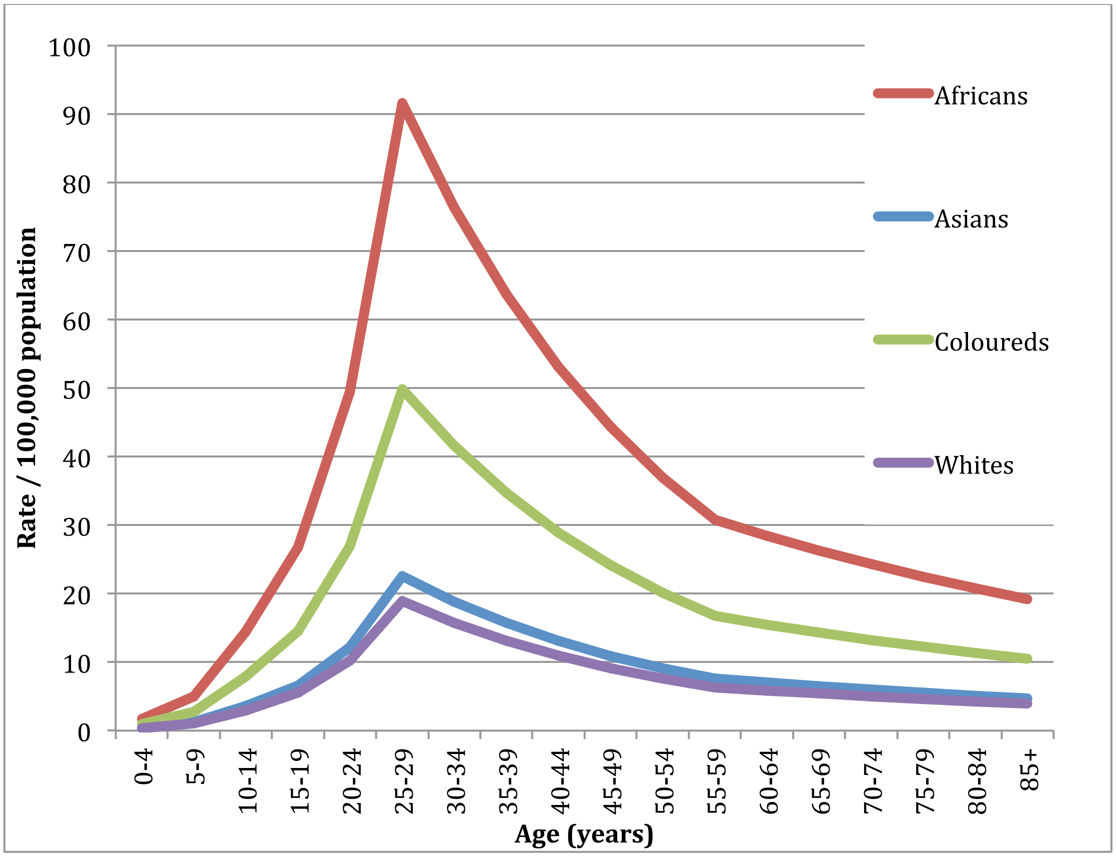

Figure 21. Homicide rates by age – derived from full model (model 17) in Table XXV

In order to assess whether the effect of *age* on homicide rates was homogenous across different race groups, an interaction term for *race* and *age* was included in a revised final model, model 20 (Table XXXI). This model suggested that there were distinct age-race interactions affecting homicide rates, which were significantly lower among Asians and Whites in the younger age categories than among Africans. However, the most notable differences followed the homicide peak at 30 years. The rate of decrease was significantly more pronounced among Coloureds than Africans, but among Asians and Whites the opposite effect was observed.

Table XXXI. The effect of *race* on homicide by *age*

(Model no) covariates included	***Log likeli***	***Dev.***	***Resid. df***	***AIC***	***BIC***
(20) *age* (cont./splined). *sex*, *race*, *day of week*, city, *year of death*	-18280	19451	25165	1.45	-235586

Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, African, Cape Town, Sunday, 2001 [constant]	-11.15 (-11.41:-10.89)	<0.01
Age (5-14)	1.16 (1.01:1.31)	<0.01
Age (15-29)	0.62 (0.58:0.65)	<0.01
Age (30-59)	-0.18 (-0.20:-0.17)	<0.01
Age (60+)	-0.18 (-0.23:-0.14)	<0.01
Sex (male)	2.03 (1.99:2.07)	<0.01
Race (Asian)	-0.60 (-1.49:0.30)	0.19
Race (Coloured)	-0.05 (-0.50:0.40)	0.82
Race (White)	-0.17 (-0.84:0.49)	0.61
Monday	-0.53 (-0.60:-0.46)	<0.01
Tuesday	-0.72 (-0.80:-0.65)	<0.01
Wednesday	-0.76 (-0.83:-0.69)	<0.01
Thursday	-0.77 (-0.84:-0.70)	<0.01
Friday	-0.38 (-0.45:-0.31)	<0.01
Saturday	0.17 (0.10:0.24)	<0.01
Durban	-0.26 (-0.33:-0.19)	<0.01
Johannesburg	-0.85 (-0.92:-0.78)	<0.01
Port Elizabeth	-0.19 (-0.27:-0.11)	<0.01
Pretoria	-1.49 (-1.57:-1.41)	<0.01
2002	0.03 (-0.03:0.08)	0.31
2003	-0.12 (-0.17:-0.06)	<0.01
2004	-0.22 (-0.28:-0.16)	<0.01
2005	-0.24 (-0.31:-0.17)	<0.01
Age (5-14), Asian	-0.60 (-1.11:-0.10)	0.02
Age (5-14), Coloured	-0.24 (-0.50:0.02)	0.08
Age (5-14), White	-1.15 (-1.57:-0.72)	<0.01
Age (15-29), Asian	0.06 (-0.06:0.18)	0.33
Age (15-29), Coloured	<0.01 (-0.06:0.07)	0.89
Age (15-29), White	0.11 (-0.04:0.26)	0.14
Age (30-59), Asian	0.11 (0.07:0.15)	<0.01
Age (30-59), Coloured	-0.06 (-0.09:-0.04)	<0.01
Age (30-59), White	0.19 (0.15:0.22)	<0.01
Age (60+), Asian	0.13 (0.01:0.26)	0.04
Age (60+), Coloured	-0.13 (-0.25:<0.01)	0.04
Age (60+), White	0.21 (0.13:0.28)	<0.01

In fact the graphical representation of model 20 (Figure 22[22]) indicated that, from age 30, there was a negligible decrease in homicide risk with increasing age among Asians and a slight increase among whites.

[22] This chart also shows the age-homicide relationship by race for females in Cape Town on a Sunday in 2001.

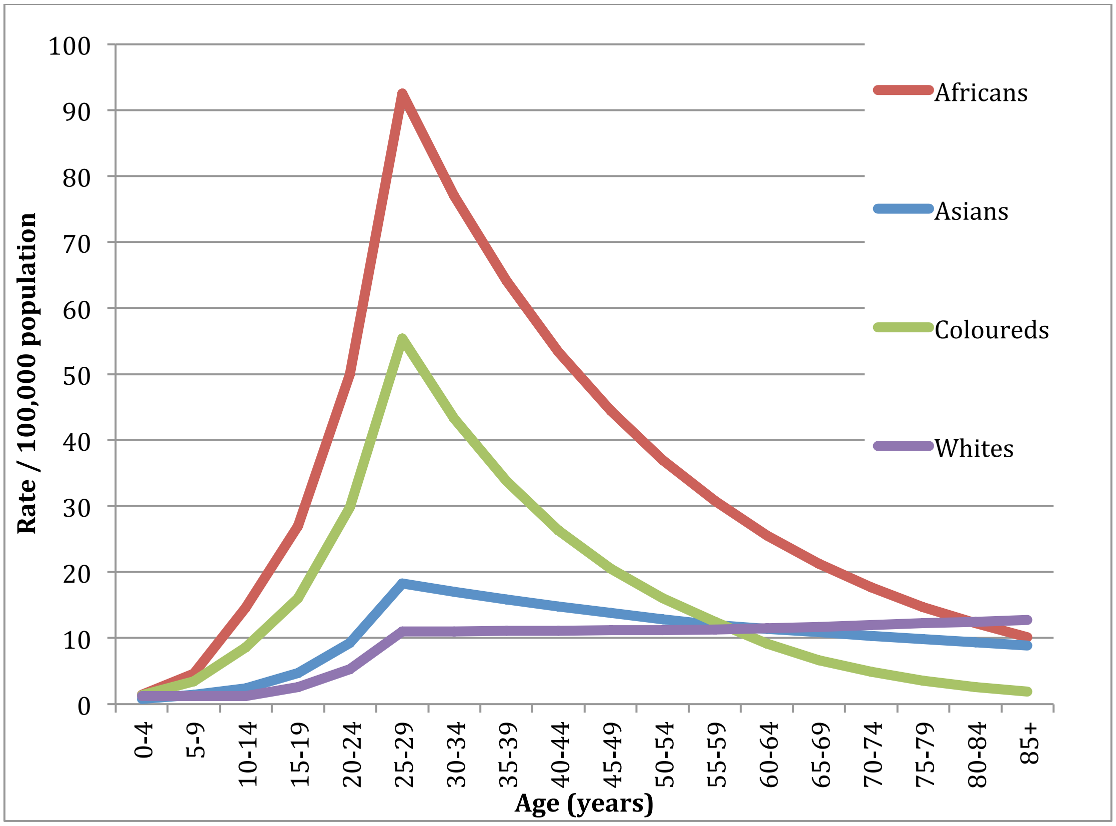

Figure 22. Homicide rates by age – derived from full model with interaction terms for *age* and *race* (model 20)

In summary, the model suggests that there is effect modification by *race* of the homicide-age effect adjusting for the other covariates treated as confounders. The more dramatic increase in homicide rates particularly among young Africans followed by Coloureds and then Asians and Whites was consistent with the hypothesis that more socio-economically marginalised communities would experience higher levels of violence among youths and young adults (*Hypothesis 2.2.1*). The negligible decrease among Asians and slight increase among Whites from 30 years of age was consistent with the hypothesis that Whites and Asians would become relatively more vulnerable than Coloured and Africans to homicide with advancing age (*Hypothesis 2.2.2*).

6.3.4. *Race* modifying the effect of *sex* (Hypothesis 2.3)

In order to assess whether the effect of *race* on homicide rates was homogenous across sexes an interaction term for *race* and *sex* was included in a revised final model, model 21 (Table XXXII).

Table XXXII. The effect of *race* on homicide by *sex*

(Model no) covariates included	*Log likeli*	*Dev.*	*Resid. df*	*AIC*	*BIC*
(21) *age* (cont./splined). *sex*, *race*, *day of week*, city, *year of death*	-18511	19913	25174	1.47	-235215

Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, African, Cape Town, Sunday, 2001 [constant]	-11.05 (-11.27:-10.83)	<0.01
Age (5-14)	1.07 (0.95:1.18)	<0.01
Age (15-29)	0.62 (0.58:0.65)	<0.01
Age (30-59)	-0.18 (-0.19:-0.17)	<0.01
Age (60+)	-0.08 (-0.11:-0.05)	<0.01
Sex(male)	2.12 (2.07:2.17)	<0.01
Race (Asian)	-1.35 (-1.57:-1.14)	<0.01
Race (Coloured)	-0.39 (-0.48:-0.29)	<0.01
Race (White)	-0.93 (-1.07:-0.80)	<0.01
Monday	-0.53 (-0.60:-0.46)	<0.01
Tuesday	-0.72 (-0.80:-0.65)	<0.01
Wednesday	-0.76 (-0.83:-0.69)	<0.01
Thursday	-0.77 (-0.84:-0.70)	<0.01
Friday	-0.38 (-0.45:-0.31)	<0.01
Saturday	0.17 (0.10:0.24)	<0.01
Durban	-0.26 (-0.33:-0.19)	<0.01
Johannesburg	-0.85 (-0.92:-0.78)	<0.01
Port Elizabeth	-0.19 (-0.27:-0.11)	<0.01
Pretoria	-1.49 (-1.57:-1.41)	<0.01
2002	0.03 (-0.03:0.08)	0.32
2003	-0.12 (-0.17:-0.06)	<0.01
2004	-0.22 (-0.28:-0.16)	<0.01
2005	-0.24 (-0.31:-0.17)	<0.01
Asian, male	-0.05 (-0.28:0.18)	0.66
Coloured, male	-0.26 (-0.36:-0.15)	<0.01
White, male	-0.77 (-0.93:-0.62)	<0.01

Model 21 showed that there were significant *race-sex* interactions among Coloureds and Whites compared to Africans. Specifically, the increased risk of homicide among males versus females was less evident among Whites as shown in Table XXXIII[23]. It should be noted that as White homicide rates were generally much lower, the differential between White females and males was also lower as shown in Figure 23. The preceding analysis

[23] The IRRs in this table were again adjusted for all other covariates and reflect the relative risk of homicide risk among males versus females of the same *race*. For example, Coloured males were 6.43 more times likely to be the victims of homicide than coloured females.

and studies in the the literature review have shown that the lower the SES the higher the homicide rates and this is particularly evident among young males, who also account for a larger percentage of the population among low SES groups.

Table XXXIII. Ratio of male versus female homicide by *race*

	IRR (95% C.I)	Inverse IRR (95% C.I)
**African*	8.30 (7.90; 8.73)	0.12 (0.11; 0.13)
**Asian*	7.89 (6.32; 9.85)	0.13 (0.10; 0.16)
**Coloured*	6.43 (5.89; 7.03)	0.16 (0.14; 0.17)
**White*	3.83 (3.31; 4.43)	0.26 (0.23; 0.30)

* Denotes statistical significance at the 5 percent level.

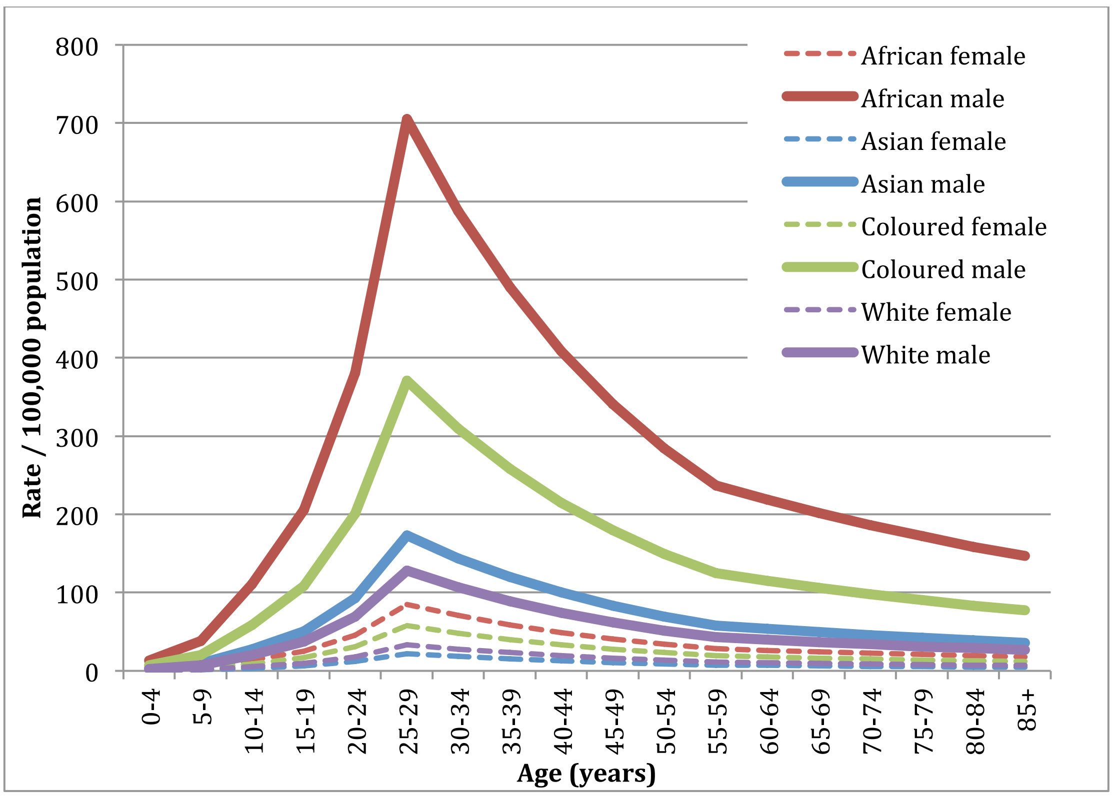

Figure 23. Homicide rates by age – derived from full model with interaction terms for *sex* and *race* (model 21)

When stratified by sex, the relative risk of homicide remained significantly different for each race (Table XXXIV) [24]. For males, the highest level of risk followed the general pattern: Africans were at significantly higher risk, followed by Coloureds, Asians and then Whites. However, among females it was Asians rather than Whites that were the lowest risk-category (Figure 23).

Table XXXIV. Relative risk of homicide among females and males by *race* compared to African

	IRR (95% C.I)	Inverse IRR (95% C.I)
Females		
**Asians*	0.26 (0.21; 0.32)	3.88 (3.14; 4.79)
**Coloured*	0.68 (0.62; 0.75)	1.47 (1.34; 1.62)
**Whites*	0.39 (0.34; 0.45)	2.54 (2.22; 2.9)
Males		
**Asians*	0.25 (0.22; 0.27)	4.08 (3.74; 4.45)
**Coloured*	0.53 (0.49; 0.56)	1.9 (1.77; 2.04)
**Whites*	0.18 (0.17; 0.2)	5.51 (5.09; 5.96)

* Denotes statistical significance at the 5 percent level.

6.3.5. The reduction in homicide rates attributable to firearm homicide decrease (Hypothesis 3)

The full model (model 17) revealed no change in homicide rates from 2001(the baseline year) and 2002 and then a significant decrease from 2002 to 2003 and a further significant decrease from 2003 to 2004 after adjusting for all the covariates. The same model was also applied individually for firearm homicides and non-firearm homicides (Table XXXV) . Whereas for non-firearm homicides (model 22) there was no significant change evident between the baseline year, 2001, and any other year for firearm homicides (model 23) there were significant decreases between the baseline year, 2001, and each year from 2003 to 2005.

[24] The IRRs reflect the relative risk of homicide relative to Africans between *race* groups for females and males adjusting for all other covariates. African females and African males are the respective baseline comparison groups. So, for example, African females were 3.88 times more likely to be the victims of homicide than Asian females and African males were 5.51 times more likely to be victims of homicide than white males.

Table XXXV. The full model with all covariates included applied to non-firearm homicide (model 22) and firearm homicide (model 23)

(Model no) covariates included

(22) *age* (continuous/splined), *sex* (categorical), *race* (categorical), *city* (categorical), *day of week* (categorical), *year of death* (categorical)

Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, African, Sunday, Cape Town, 2001 [constant]	-10.88 (-11.12:-10.64)	<0.01
Age (5-14)	0.82 (0.68:0.95)	<0.01
Age (15-29)	0.6 (0.57:0.64)	<0.01
Age (30-59)	-0.17 (-0.18:-0.15)	<0.01
Age (60+)	0 (-0.04:0.04)	0.83
Sex(male)	1.87 (1.82:1.92)	<0.01
Race (Asian)	-1.49 (-1.61:-1.37)	<0.01
Race (Coloured)	-0.52 (-0.6:-0.45)	<0.01
Race (White)	-1.69 (-1.78:-1.59)	<0.01
Monday	-0.72 (-0.8:-0.64)	<0.01
Tuesday	-1 (-1.09:-0.91)	<0.01
Wednesday	-1.06 (-1.15:-0.97)	<0.01
Thursday	-1.06 (-1.15:-0.97)	<0.01
Friday	-0.56 (-0.65:-0.47)	<0.01
Saturday	0.19 (0.11:0.27)	<0.01
Durban	-0.53 (-0.61:-0.45)	<0.01
Johannesburg	-1.41 (-1.49:-1.32)	<0.01
Port Elizabeth	0.1 (0.01:0.18)	0.03
Pretoria	-1.79 (-1.89:-1.69)	<0.01
2002	**0.02 (-0.04:0.09)**	**0.48**
2003	**-0.03 (-0.1:0.04)**	**0.41**
2004	**-0.06 (-0.13:0.01)**	**0.09**
2005	**-0.02 (-0.1:0.07)**	**0.72**

(23) *age* (continuous/splined), *sex* (categorical), *race* (categorical), *city* (categorical), *day of week* (categorical), *year of death* (categorical)

Parameter	Coefficient (95% CI)	P-val
Age (0-4), female, African, Sunday, Cape Town, 2001 [constant]	-12.79 (-13.14:-12.45)	<0.01
Age (5-14)	1.46 (1.28:1.64)	<0.01
Age (15-29)	0.62 (0.59:0.66)	<0.01
Age (30-59)	-0.19 (-0.21:-0.18)	<0.01
Age (60+)	-0.2 (-0.25:-0.15)	<0.01
Sex(male)	2.21 (2.15:2.26)	<0.01
Race (Asian)	-1.33 (-1.43:-1.23)	<0.01
Race (Coloured)	-0.74 (-0.82:-0.65)	<0.01
Race (White)	-1.48 (-1.57:-1.39)	<0.01
Monday	-0.33 (-0.41:-0.26)	<0.01
Tuesday	-0.47 (-0.55:-0.39)	<0.01
Wednesday	-0.49 (-0.57:-0.41)	<0.01
Thursday	-0.51 (-0.58:-0.43)	<0.01
Friday	-0.2 (-0.27:-0.12)	<0.01
Saturday	0.16 (0.08:0.23)	<0.01
Durban	0.01 (-0.06:0.08)	0.77
Johannesburg	-0.42 (-0.49:-0.35)	<0.01
Port Elizabeth	-0.78 (-0.88:-0.68)	<0.01
Pretoria	-1.21 (-1.3:-1.12)	<0.01
2002	0.03 (-0.03:0.09)	0.33
2003	**-0.19 (-0.25:-0.13)**	**<0.01**
2004	**-0.37 (-0.44:-0.31)**	**<0.01**
2005	**-0.46 (-0.53:-0.39)**	**<0.01**

Pairwise comparison for each subsequent year (Table XXXVI) showed that there were significant year-on year decreases in firearm homicide from 2002 to 2005.

Table XXXVI. Pairwise baseline and non-baseline comparisons for *year of death* for firearm homicide

	IRR (95% C.I)	Inverse IRR (95% C.I)
Year of death		
2002 vs. 2001	1,03 (0,97; 1,10)	0,97 (0,91; 1,03)
**2003 vs. 2002*	0,80 (0,75; 0,85)	1,25 (1,17; 1,33)
**2004 vs. 2003*	0,83 (0,78; 0,89)	1,20 (1,12; 1,28)
**2005 vs. 2004*	0,91 (0,85; 0,98)	1,09 (1,02; 1,18)

* Denotes statistical significance at the 5 percent level.

The estimated incidence rate ratios (IRRs) for firearm homicide in 2003, 2004 and 2005 compared to 2002, the year in which homicide peaked, overall and for *sex*, *race* and *city* are shown in Table XXXVII, which also shows the reduction effect as IRR – 1[25]. Assuming that without the introduction of the FCA the homicide rate would have remained constant year-on-year, the risk reduction described in Table XXXVII suggests that 4405 (3688; 5121) lives were saved across the five cities from 2003 to 2005. The estimated totals year-on-year were as follows[26]:

- 2003 : 945 (708; 1181);
- 2004 : 1577 (1338; 1864); and
- 2005 : 1883 (1642; 2077).

[25] In this table the risk reduction is shown overall and for *sex*, *race* and *city* adjusted for all other covariates. So, for example, in Durban there was a 28 percent reduction in firearm homicide from 2002 to 2005 and among Africans in all five cities there was a 38 percent reduction from 2002 to 2005.
[26] The totals have been adjusted to reflect the relative increases in total populations across the five cities year-on-year.

Table XXXVII. Incident rate ratio (IRR) and reduction effect size for firearm homicide by *year of death* (relative to 2002)

	IRR (95% CI)	Reduction effect size (95% CI)
Overall		
2003	0.80 (0.75; 0.85)	20% (15%; 25%)
2004	0.67 (0.62; 0.71)	33% (28%; 39%)
2005	0.61 (0.57; 0.66)	39% (34%; 43%)
Sex		
Males, 2003	0.8 (0.74; 0.85)	20% (15%; 26%)
Males, 2004	0.66 (0.61; 0.71)	34% (29%; 39%)
Males, 2005	0.6 (0.56; 0.65)	40% (35%; 44%)
Females, 2003	0.84 (0.72; 0.98)	16% (2%; 28%)
Females, 2004	0.78 (0.66; 0.92)	22% (8%; 34%)
Females, 2005	0.68 (0.57; 0.81)	32% (19%; 43%)
City		
Cape Town, 2003	0.75 (0.65; 0.87)	25% (13%; 35%)
Cape Town, 2004	0.5 (0.42; 0.6)	50% (40%; 58%)
Cape Town, 2005	0.54 (0.46; 0.64)	46% (36%; 54%)
Durban, 2003	0.91 (0.82; 1.01)	9% (-1%; 18%)
Durban, 2004	0.78 (0.7; 0.86)	22% (14%; 30%)
Durban, 2005	0.72 (0.65; 0.81)	28% (19%; 35%)
Johannesburg, 2003	0.83 (0.75; 0.91)	17% (9%; 25%
Johannesburg, 2004	0.66 (0.58; 0.74)	34% (26%; 42%
Johannesburg, 2005	0.59 (0.53; 0.66)	41% (34%; 47%
Port Elizabeth, 2003	0.74 (0.57; 0.95)	26% (5%; 43%
Port Elizabeth, 2004	0.73 (0.57; 0.94)	27% (6%; 43%
Port Elizabeth, 2005	0.72 (0.55; 0.94)	28% (6%; 45%
Pretoria, 2003	0.48 (0.39; 0.59)	52% (41%; 61%
Pretoria, 2004	0.84 (0,72; 0.98)	16% (2%; 28%
Pretoria, 2005	0.41 (0.34; 0.5)	59% (50%; 66%
Race		
African, 2003	0.81 (0.76; 0.87)	19% (13%; 24%)
African, 2004	0.71 (0.66; 0.76)	29% (24%; 34%)
African, 2005	0.62 (0.57; 0.67)	38% (33%; 43%)
Asian, 2003	0.93 (0.69; 1.25)	7% (-25%; 31%)
Asian, 2004	0.64 (0.47; 0.88)	36% (12%; 53%)
Asian, 2005	0.79 (0.59; 1.07)	21% (-7%; 41%)
Coloured, 2003	0.71 (0.58; 0.86)	29% (14%; 42%)
Coloured, 2004	0.39 (0.31; 0.48)	61% (52%; 69%)
Coloured, 2005	0.48 (0.39; 0.59)	52% (41%; 61%)
White, 2003	0.8 (0.62; 1.03)	20% (-3%; 38%)
White, 2004	0.72 (0.54; 0.94)	28% (6%; 46%)
White, 2005	0.74 (0.57; 0.95)	26% (5%; 43%)

This analysis supports the hypothesis that the significant decline in homicide across the five cities from 2003 was attributable to the decline of firearm homicides after adjusting for the effects of the other covariates, all of which were independent predictors of homicide rates.

In summary, the multivariable analysis proceeded from a categorical representation of the age-homicide relationship (model 1) to a model that represented age as a continuous splined variable (model 2). This crude model was the foundation from which the influence of different covariates on the age-homicide relationship were analysed. Models 3 to 8 comprised trivariate analyses in which each covariate was introduced to the crude model separately, whereafter (in models 9 to model 16) combinations of additional covariates were added to the model. The full model (model 17) included all covariates and provided the best fit. The same model was also applied to an alternative data set with missing age values imputed to test sensitivity (model 18). Models 19 to 21 were also based on the full model (model 17), but included interaction terms for *race* and *city*, *race* and *age*, and *race* and *sex* respectively. In models 22 and 23, the full model (model 17) was applied to non-firearm homicides and firearm homicides respectively.

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CHAPTER 7: DISCUSSION

This is one of only three studies of injury mortality based on mortuary data that have gone beyond simple descriptive statistics and used more complex multivariable methods to gain deeper understanding of the determinants of homicide with a view to driving more effective prevention through an analysis of the need for and identification of appropriate interventions and their evaluation over time.

The findings of this thesis are discussed in a critical evaluation of pre-existing findings, perceptions and policy direction related to homicide mortality in South Africa and further afield. Section 7.1 summarises the results pertaining to the extent and distribution of homicide mortality in South Africa. Section 7.2 discusses the role of explanatory variables as independent predictors of homicide rates as set out in Hypothesis 1 in Chapter 4. Section 7.3 discusses interactions between key variables (Hypothesis 2) and section 7.4 discusses the effect of the Firearms Control Act (FCA) on firearm homicide rates (Hypothesis 3). In section 7.5 the utility of the study and of mortuary-based injury surveillance systems in general are discussed. Section 7.6 describes the limitations of the study and Section 7.7. reflects upon possible future developments that could shape the further enhancement of the system.

7. 1. The extent and distribution of homicide mortality

The data presented in this thesis reflect the unusually high homicide rates in South Africa's major cities. Comparison with police data attested to the congruence between the mortuary and police data from the same cities for the period of this study. However, this was not the case when national police data were compared with national estimates based on the mortuary-based surveillance. Norman et al.'s (2007) estimate of approximately 27,570 homicides in 2000 was 27 percent higher than the 21,683 recorded by the police in their annual murder statistics (Criminal Justice Monitor no date). This suggests that underreporting of homicide by the police may be more likely to occur in rural areas, or at least in rural and urban areas other than the five cities included in this thesis. Schönteich and Louw (2001) note that many crimes are either not reported to police by victims or witnesses, or simply not recorded by police, which is why victim surveys tend to report 60 percent to 70 percent more crimes than official statistics. Furthermore, the withholding of timeous crime data, which are only released annually in South Africa is not only unconstitutional, but also serves to position the police as the sole (and ineffective) custodians of safety. The literature review clearly shows that as much as violence is a multi-dimensional problem with numerous risk and protective factors, so too prevention requires a concerted intersectoral preventive response.

The combined age standardised homicide rate for the five cities in this thesis ranging from 60.3 per 100,000 population in 2001 to 45.4 in 2005 was consistent with Norman et al.'s findings, which estimated the national homicide rate at more than eight times the global average for men, and five times the global average for women in 2000, viz. an age-standardised homicide rate of 64.8 per 100 000 population for both sexes combined (Norman et al (2007). However there were discrepancies in the city homicide rates compared to their findings. The age-standardised homicide rates for South Africa's major cities (Table XV in section 6.1 of the Results chapter) revealed that Cape Town and Port Elizabeth were recording substantially higher rates in 2001 than those estimated by Norman, whereas the homicide rate in Pretoria was considerably lower. Groenewald et al. (2010) have analysed local level mortality data and highlighted disparities in a range of fatal health outcomes, including homicide, between sub-districts of Cape Town. At face value the significantly higher rates in the Khayelitsha sub-district suggest an association with poverty and inadequate infrastructure. In this thesis *race* serves as a proxy for measures of inequality. Certainly, the race profile as well as the distribution of homicide by *race* differed between cities as Cape Town and Durban, for example, had far larger Coloured and Asian populations respectively than the other cities. There are several other possible predictors of homicide available from the surveillance data that might explain the differences in homicide across cities before the effect of the cities themselves can be considered.

Among the predictors identified in the literature review were age and sex. As set out in section 6.2 of the Results chapter, the distribution of homicide by *sex* and by *age* differed markedly from city-to-city. It is also worth noting that the distribution of *age* and *sex* were not uniform - there being a considerably higher proportion of young adult men in Johannesburg than there were in other South African cities. Calendar effects were evident, with disproportionate homicide incidence at weekends in cities such as Port Elizabeth and Cape Town, which also recorded the highest proportions of alcohol positive cases.

7.2. *Age*, *sex* , *race*, *city*, *day of week*, and *year of death* as independent predictors of homicide

The multivariate analysis was instructive in assessing the role of each of the covariates (*age*, *sex*, *race*, *day of week*, *city* and *year*) as independent predictors of homicide. It was shown that the homicide-age relationship could be usefully approximated as a log-linear model with age-splines at 15, 30 and 60 years. The benefit of this approach was that there was a good fit of the modeled to the actual data, but there were considerably fewer parameters than would have been utilised if age had been modeled as a categorical variable. This simplicity, allowed for a far easier interpretation of the effect of the different co-variates.

Each covariate was shown to be an independent predictor of homicide in that the inclusion of the other covariates did not fundamentally alter the magnitude of the regression or slope parameter of the covariate being tested. E.g. in the case of *age* the inclusion of *sex*, *race*, *city*, *day of week*, and *year of death* did not alter the structure of the age-spline model. Homicide rates increased gradually from 0 to 14 years, rose rapidly from 15 to 29 years at which point they peaked, before declining rapidly until the age of 60 years, whereafter the rate of decline was less evident.

Age, *sex* and *race* were shown to be the most influential predictors of homicide rates based on their overall impact on the goodness of fit of the modelling as measured by AIC and BIC. The age pattern was certainly consistent with many other LMICs, particularly those in Latin America and the Carribean, where the highest rates of violence are concentrated among youth especially young males. The only other setting with high homicide rates and a different age peak was Eastern Europe, where homicides tend to peak among older males aged 30 to 59 years (Mathers, Inoue et al. 2002, Pridemore 2003). In Russia, this older age group was associated with the highest level of alcohol consumption (Pridemore 2002), with Welch (2009) also attributing the increase in homicide in former Soviet bloc countries to the social disorganisation emanating from the sudden social and economic collapse affecting an unprepared cohort of citizens. It is conceivable that the end of Apartheid in South Africa may have resulted in similar social disorganisation and certainly the high homicide rates in the mid-1990s are supportive of this theory.

For *sex*, as expected males were at higher risk than females. However this ratio in South Africa was more pronounced than most other countries except some in Latin America. For *race* the results were consistent with the literature, which suggests that more deprived groups are at greater risk of homicide and violence. This was further emphasised by the analysis of the *age* – *race* interaction in that there was a disproportionately higher homicide risk among young Africans, reflecting the combined effects of lower socio-economic status, higher levels of unemployment and lack of access to recreational opportunities (Hypothesis 2.2.1). As noted in section 5.5, race currently serves as a proxy for SES and may mask other important effects that may also be associated with other known risk for homicide. However, the results suggest that these risks are either correlated with SES, or not significant enough to affect the strong association with SES and homicide risk.

The prominence of these three variables (*age*, *sex* and *race*) and the sharp peak in incidence among young African men is consistent with the notion of more marginalised groups being at greater risk both of perpetrating, and being the victims of, violence. Young African men in South Africa have become increasingly excluded after the end of Apartheid, both socially and economically, with limited employment and recreational opportunities, and high levels of alcohol and other drug abuse. A further catalyst among gangs of urban African youth is the dominant ideal of masculinity, which is Morrell (1998) describes as being primarily asserted by violence “against other gangs, against workers, against symbols of authority and against women” (Morrell 1998). Females account for up to 40 percent of physical trauma cases presenting at the primary level (Govender, Matzopoulos et al. 2012) and female as well as male homicide rates in South Africa are higher than global averages.

The homicide rates by *age* and *race* did, however, contradict the suggestion by Seedat et al. (2009) that South Africa’s highest homicide rates were among Coloureds. Despite the controversial and counterintuitive nature of their finding, considering the strong known association between violence and SES, Seedat et al. did not explain their analysis in any detail, relying instead on a survey focussed entirely on women as victims of intimate partner violence (Abrahams, Jewkes et al. 2009), and a book in the popular press, *A country at war with itself*, about high crime rates in South Africa (Altbeker 2007). However, Altebeker’s book makes no mention of the Coloured homicide rate, and it is possible that the citation is a misattribution of another Altbeker (2008) paper that is also referenced in Seedat et al.’s report. Altbeker provides summary data from four sources, that indicate that Coloureds may be overrepresented in murder statistics: (1) the NIMSS (2002), (2) two studies from *SA Crime Quarterly* (Thomson 2004, Leggett 2004), (3) a docket analysis of murders recorded by the police (SAPS [South African Police Service]

2004), and (4) an earlier write-up of the same intimate partner violence study cited by Seedat et al., compiled in this case by Mathews, Abrahams et al (2004). Altbeker describes this evidence as being ambiguous and he notes the following:

> (1) As well as being urban-biased (and hence underrepresenting Africans), he observed that the NIMSS provided full coverage of Cape Town and Kimberley two centres with disproportionately large Coloured populations;
> (2) Both Thomson (2004) and Leggett (2004), who draw on Thomson's analysis, utilised the NIMSS annual reports for 1999, 2000 and 2001 for their analysis and ignored the overrepresentation of Coloureds (and Whites) in the NIMSS data set;
> (3) The SAPS docket analysis represents 11 percent of 23 289 murder dockets that had been closed in 2001. This sample was not representative of all cases that were opened in that 21 percent of the cases were from the Western and Northern Cape, whereas only 18 percent of murders were recorded in these provinces. The inference that can be drawn from the data is that Coloureds were overrepresented among cases in which the identity of the perpetrator was known to the police. This may be indicative of more violence occurring within domestic relationships and between members of the community that are known to one-another; and
> (4) Whereas Altbeker does concede that the intimate partner violence study was nationally representative, he suggests that the identification of intimate partners as perpetrator may reflect better policing in certain provinces, in this case the Northern and Western Cape, which coincidentally also have relatively larger Coloured populations. Altbeker cites as evidence Redpath's analyisis of 2002 conviction rates for murder in which the Western and Northern Cape had the highest rates of 46 percent and 27 percent respectively, compared to a national average of just 18 percent (Redpath 2002).

Certainly Altbeker casts considerable doubt on the evidence for any inferences about high Coloured homicide rates and so Seedat et al. were mistaken in citing Altbeker's analysis as providing supporting evidence for higher homicide rates amongst Coloureds. Ironically, Altbeker's earlier 2008 chapter appears in a book edited by several of the authors of Seedat et al.'s later 2009 report.

For *day of week* the prominence of the three weekend days is not unexpected, nor the ranking. Given the association between alcohol and violence it is most likely that day of week is a proxy or indicator for increased social interaction and the use of alcohol and other drugs. Certainly, Saturday followed by Sunday and Friday which are shown in section 6.1 to have the highest homicide incidence rates by day of the week are the days in which the highest volumes of alcohol are likely to be consumed.

For *city*, although the superficial analysis in the NIMSS annual reports had suggested that homicide rates differed by city and that homicide rates in the Gauteng cities of Johannesburg and Pretoria were lower, these had not been shown in a multivariate model that controlled simultaneously for the influence of all the other covariates. It is noteworthy, however, that the NIMSS results were contrary to the popular perception that Gauteng was more violent than the Western Cape. This perception is corroborated to some extent by the 2007 Victim Survey results prepared for the Institute for Security Studies by Markinor (Institute for Security Studies 2008) in which Gauteng respondents were more concerned about personal safety during daylight hours and after dark than respondents in any other province. However, the results of the multivariate analysis clearly emphasise the particularly and substantially higher violence burden in Cape Town relative to other centres and the need for a co-ordinated effort to reduce violence. The findings thus corroborate and explain further and with greater accuracy these differences, which indeed are contrary to the popular perception, and which have greater potential to inform rational and appropriate interventions. These differences will be elaborated on in the analysis by *city* and *race* in section 7.3.

7.3. Interactions between key variables

City and race

The analysis of the *city-race* interaction suggested that there was certainly an empirical basis for the perception of greater homicide risk among Whites in Johannesburg (Hypothesis 2.1). Whereas overall homicide risk in Cape Town was higher than in any other city and Africans experienced the highest levels of risk, followed by Coloureds, Asians and then Whites, analysis of homicide patterns by *race* showed that the magnitude of the race effect differed significantly from city-to-city. Cape Town was the highest risk city for Africans (who experienced the least risk in Johannesburg and Pretoria), whereas Asians and Coloureds experienced their highest homicide risk in Port Elizabeth, and Whites in Johannesburg. These highly original findings arising from a more sophisticated analysis are of considerable significance in that the expected pattern is that the lower SES group has the highest homicide rates across the board. These results offer improved explanatory potential for popular perceptions and white migration patterns and can inform prevention interventions. According to the population data used in the multivariable analysis Cape Town had the fastest growing white population during the study period, which is consistent with both perceptions of relative safety, and the relatively lowest homicide risk for white in the city with the highest mortality incidence.

Reinforcing perceptions of Cape Town being relatively safe, is a common discourse that foregrounds the intimate relationships that frequently exist between the perpetrators and victims of homicide in South Africa. A recent op-ed article by Western Cape Premier, Helen Zille, in which she downplays the high homicide rate in Cape Town is indicative. Zille suggests that in the South African context, as homicide is most frequently committed by an acquaintance or family member (78 percent according to the 2011 Victims of Crime Survey(Statistics South Africa 2011)), the homicide rate is a poor indicator of the risk of violence at the hands of a random stranger (Zille 2012). Zille suggests instead that “aggravated robberies”, i.e. robberies with high levels of violence that might typically involve the theft of expensive items such as in car hi-jacking, are more appropriate indicators of overall crime levels and cites the South Africa Survey published by the South African Institute of Race Relations(2012), which depicts Johannesburg as having the highest rate of aggravated robbery cases, followed by Port Elizabeth, Durban and then Cape Town. However, there is contradictory evidence from this report showing that Cape Town has a far higher murder to robbery ratio than other cities, i.e. one murder for every six robberies compared to 1:8 in Port Elizabeth and Durban and 1:15 in Johannesburg.

In essence the Premier is reflecting three common wisdoms that are being propagated by security agencies based on unreliable data sources and analyses, viz.:

1: *the murder rate has been dropping consistently*. This is indeed true, but the role of gun control in affecting this decline is not mentioned (see section 7.4) with the implication that the decline is due to improved policing.

2: *perpetrators of homicide are not strangers intent on hijacking or robbing random victims, but rather known to the victim*. Whereas violence may be commonplace within the domicile or between close personal acquaintances in low SES communities, the higher risk among more vulnerable groups within wealthier SES communities, the elderly and women (as discussed in the two sub-sections that follow which describe the *age-race* and *race-sex* interactions), suggests that the targeting of specific victims is indeed an important and substantial contributor to homicide in South Africa. Whether such incidents are primarily at the hands of known assailants or random in nature is not self-evident from the available data;

3: *the Western Cape, specifically, is a desirable safe haven from violence*, although the analysis provides evidence that supports (in the case of Whites) and contradicts this position (particularly for Africans).

A possible motivation for the security agencies in promoting this understanding is that they are able to downplay perceptions of inefficiency in that violent crime is relegated to a domestic or private domain that is not readily "police-able". The Western Cape has an incentive to promote this perception of relative safety as it satisfies a political message of better governance and also serves to protect the tourism industry. Similarly misleading is the foregrounding of gang violence in the provincial security agenda, which is concentrated primarily in the Coloured community, whereas it is clear from this analysis that the African community is most affected by homicide.

This understanding has popular appeal, as the prospect of violence and even fatal violence at the hands of a known assailant might be conceived as less alarming than violence at the hands of a stranger. The underlying assumption appears to be that a murder committed by a known assailant in the private sphere is somehow the victim's "fault" and does not represent a general threat to the "innocent" citizenry that prudently avoids such hazardous relationships. Certainly the understanding also serves to allay "White fears", in this case encompassing the upper-middle classes more generally and, of course, tourists that contribute substantially to the Western Cape economy. These fears are foregrounded in "White-biased" media reportage in mainstream (including overseas) papers that profiles homicides and aggravated assaults directed at the wealthier echelons of South African society or at foreign tourists.

This understanding also relates to a perceived difference by SES in the risk of homicide victimisation. The domestic nature of violence in the family and in the proximal community that is brought about by dire social circumstances may rightly be seen as the preserve of lower SES communities that experience a preponderance of the risk factors detailed in section 2.2 of the literature review (chapter 2). As White homicide rates are indeed lower in Cape Town than in Johannesburg the rates of homicide among the overall population of cities can be discounted by the wealthy. The higher overall rate in Cape Town is due to the higher rates among the Africans and Coloured populations, which are socially compartmentalised in communities with high levels of violence.

There are, however, several flaws in this reasoning. First, there is a wide spectrum of human relations that determine whether people are known to one-another, from immediate family and friends, to colleagues and acquaintances in the community. It is conceivable, for example, that in many homicides involving gangs or organised crime syndicates the protagonists are known to one-another. Aggravated robberies as well as homicides affecting the wealthy certainly involve, on occasion, domestic employees or part-time labourers that are known to the victims. This complexity is resolvable by employing a dichotomous stranger/known-perpetrator stratification.

Second, it is almost certainly more likely that less wealthy citizens experience a greater risk across the full spectrum of violence typologies described in section 2.2 of the literature review (chapter 2), including aggravated robberies by strangers. If certain types of crime are more prevalent in a particular jurisdiction, e.g. aggravated robberies in Johannesburg, it does not necessarily follow that poor people are somehow less affected.

Third, the use of police data to measure the incidence of violence other than fatal violence is extremely problematic. There are inherent biases in the data, particularly as the police are evaluated on their ability to reduce crime. As these decreases are measured by police statistics there is an overt incentive to under-report, as evidenced by the recent prosecution of several senior commissioned police officers for manipulating crime statistics (Newham 2011). Even if this were not the case and every case reported to the police was accurately recorded the data would still not be reliable. Data from the 2011 Victims of Crime Survey suggest that only about half of assaults (53 percent) and a third of robberies (39 percent) were reported to the police (Statistics South Africa 2011).

Perhaps the most problematic aspect of all is the potential polarisation of the safety agenda, downplaying the very real risks of violence afflicting most of Cape Town's citizens, as shown by the significantly higher overall homicide rate, the most reliable measure of violence, simply because the wealthy are relatively safer than in Johannesburg. This perspective implies that governance and policing in Cape Town is effectively addressing violence which is preventable (violence perpetrated by strangers) , and ignores the lack of safety for the poor. There is an urgent need to apply a concerted and sustained multi-sectoral approach that addresses immediate risks that can be ameliorated in the short to medium term, while prioritising the necessary social investments to affect fundamental long-term changes in the circumstances and behaviours that lead to violence (Matzopoulos, Bowman et al. 2010). The safety agenda across all cities would also be well served by identifying the risk factors that increase vulnerability among the wealthy in Johannesburg relative to other cities.

Age and race

Another deviation from the typical homicide pattern became apparent with the examination of the *age*-*race* interaction. Whereas Africans and Coloureds followed the typical age pattern consistent with many other LMICs as described previously, the homicide rates among elderly Whites and Asians were considerably higher than among Africans. This was consistent with Hypothesis 2.2, which suggested that homicide patterns by *age* would differ by *race*, noting again that *race* was used as a proxy variable for SES in this thesis with White, Asian, Coloured and African, used to denote decreasing levels of SES. Young Africans were expected to experience higher homicide risk, due to their lower SES, higher levels of unemployment and lack of access to recreational opportunities (Hypothesis 2.2.1); and homicide risk was also expected to be relatively higher among elderly whites followed by Asians (Hypothesis 2.2.2) on the premise that advanced age and wealth increase homicide risk and vulnerability.

This suggests that for the wealthy there appears to be a different constellation of component causes that determine homicide risk. Certainly, *age*, *sex, day of week* and *city* are important predictors and follow a similar pattern of risk among the younger age groups with high SES - as with South Africans of lower SES - but the higher risk in the older age group suggests that “vulnerability” also increases the risk. In this instance advanced *age* serves as a proxy for vulnerability among the wealthy. The previous sub-section suggests that the wealthy in Johannesburg are more vulnerable than in other cities.

Sex and race

The results suggest that females are protected in some sociocultural way from homicide, but the introduction of a *sex-race* interaction also suggested considerable differences by SES. There is certainly a range of risk factors for violence against women in intimate and domestic settings that differ considerably according to SES, which are sure to place women in low SES communities at greater risk. However, the results suggest that there may still be considerably less variation than for male homicide in these communities, where men are exposed to increased risk within, but particularly outside the home. Thus, the higher female to male ratio among Whites may be attributed to the abnormally high homicide rates among males in low SES communities. In higher SES communities, with better overall safety and security homicide is more randomly distributed, affecting males and females more evenly. In addition, higher SES is associated overall with lesser interpersonal violence as a solution applied to interpersonal disagreement and conflict inside and outside the domestic situation.

As with the *age-race* interaction, the *race-sex* interaction supported an explanation of vulnerability among the wealthy in that females accounted for a higher percentage of homicides among Whites than any other group. White females also experienced higher homicide risk than Asian females, which was contrary to the expected finding of the lowest risk amongst the highest SES strata.

The other important finding resulting from examination of the *race-sex* interaction was the rejection of Hypothesis 2.3, which predicted that Coloured women would be at significantly higher risk of homicide than women in other race groups based on a representative national study of female homicide in 1999 (Mathews, Abrahams et al. 2004). The analysis showed instead that the relative risk of homicide for Coloured females was significantly lower than for African females(Mathews, Abrahams et al. 2004). This may reflect a relative increase in homicide risk among African females since 1999, but is more likely to represent the relatively higher risk of violence facing African women in urban areas possibly as a result of their increased vulnerability in urban spaces.

The evidence for higher homicide rates in Coloureds was refuted in section 7.2, but this may not necessarily apply to female homicide rates overall. As the data in this thesis are biased to urban settings, the results reflected the relatively higher risk of violence facing African women in urban areas. It is conceivable that the overall homicide rate among African women might be considerably lower if rural areas were taken into account (and where there are relatively fewer Coloured women). This is supported by at least one study of homicide in a rural setting with Meel's (2004) analysis indicating that women accounted for just 10 percent of homicides in the Transkei in the 1990s compared to 19 percent in the national figures for 2000 estimated by Norman et al. (2007).

7.4. The decrease in firearm homicide coinciding with gun control legislation

Superficial analysis of homicide by year in the NIMSS annual reports had suggested that homicide rates had peaked in 2002 and that there had been a substantial decrease in the rate of homicide from 2002 in most cities. It also appeared as though the decrease in homicide was associated with a decrease in firearm violence specifically, as non-firearm homicide rates remained relatively stable. Hypothesis 3 stated that this reduction was solely due to the variability in the firearm homicide rate. The multivariable analysis confirmed that the significant decline in homicide across the five cities from 2003 was attributable exclusively to the decline of firearm homicides after adjusting for the effects of the other covariates.

It has been shown internationally that much of the variation between countries in national homicide rates can be explained by the extent of firearm homicide, as the total homicide rate in countries is closely associated with the rate of firearm homicides (Bhalla, Matzopoulos et al. (in press)). The enforcement of stricter gun control as a result of the Firearms Control Act of 2000 is a seemingly obvious explanation for the decline in firearm homicide in South Africa, but inferring causality is rather more complicated. Unlike in the case of pharmaceutical and biomedical research, public health interventions typically rely on observational rather than experimental research. In the case of upstream interventions, such as in the case of the Firearms Control Act, it is not possible to apply the most rigourous of study designs to test intervention effects such as randomised controlled trials. Instead reliance must be made on a before-after approach, comparing the incidence after the intervention with the incidence before. The intervention in this case was a reduction in the gun pool due to activities in anticipation of the FCA's promulgation in 2004. This included various firearm amnesties and hand-ins, in which legal and illegal guns were recovered by the authorities, and seemingly more rigorous application of existing licensing conditions by the SAPS Central Firearms Registry even before the Act was implemented, as will be described in the discussion that follows. The same criteria for inferring causality in observational epidemiological studies still apply in the case of a before-after study design. Bradford-Hill's criteria for inferring causality include: Strength of association, Consistency, Specificity, Temporality, Biological gradient, Plausibility, Experiment, Analogy and Coherence.

Strength of association

The stronger an association between an outcome and an explanatory variable in the absence of known biases, the more likely it is that there is causal relationship. The incidence rate ratios (IRRs) for firearm homicide in 2003, 2004 and 2005 compared to 2002, the year in which homicide peaked provide suitable measures of relative risk to reflect this association. A more than two-fold (30 percent) relative risk is considered to be indicative likely causation and to be unlikely to explained by unknown or unsuspected confounders.

In summary the IRRs point to significantly lower relative risks of 20 percent, 33 percent and 39 percent in 2003, 2004 and 2005 respectively compared to 2002, the year in which firearm homicide peaked. These reductions were also consistent across the range of sub-groups and locations. For example, the IRR among males in 2005 suggested a relative risk of 40 percent in gun deaths in 2005 compared with 2001. Among females this was 32 percent.

For the five cities, the IRR indicated a 39 percent decline from 2002 to 2005. In Durban there was a 28 percent decline from 2002 to 2005. In Johannesburg there was a 49 percent decline from 2002 to 2005, in Port Elizabeth a 21 percent decline from 2002 to 2005 and in Pretoria a 55 percent decline from 2002 to 2005.

Declines were also evident when the data were disaggregated by race, as follows:

- a 38 percent decline from 2002 to 2005 among Africans;
- a 21 percent decline from 2002 to 2005 among Asians;
- a 52 percent decline from 2002 to 2005 among Coloureds; and
- a 26 percent decline from 2002 to 2005 among Whites. Again the pattern that emerges is that Whites (and Asians) experience the lowest crime rates of whatever type and interventions have the largest effect among Africans and

coloureds because the baseline fatality rates before the introduction of the legislation were so much higher. It is also worth noting that firearm homicide peaked in 2001 among Whites. The decrease was evident from 2002 compared to 2003 among other race groups. This is consistent with gun ownership being concentrated among Whites at that time, and their experiencing a more immediate benefit of compliance with the stricter licensing conditions.

Consistency

The replication of similar findings in studies by different investigators at different times and across different settings is also consistent with a causal relationship. In the case of gun control there is a body of literature describing the effects of stricter regulation from a number of countries and settings (e.g. Australia, Colombia, UK, Austria). The latest evidence is summarised in a forthcoming review prepared by researchers at Liverpool John Moores University supported by the World Health Organization and the Cochrane Public Health Group (Bellis, Jones et al. 2011) – see Table XXXVIII. The review examined the effectiveness of legislation and regulation (including bans, licensing schemes, minimum ages for buyers, background checks and safe storage requirements) on firearm-related violence.

Although the interrupted time series designs of the studies (a version of before-after studies in which time-series before and after are compared), precluded a quality rating using tools such as the Quality Assessment Tool for Quantitative Studies (National Collaborating Centre for Methods and Tools 2008), which favoured randomised controlled trials, the researchers concluded that there was emerging evidence from high and middle income countries that introducing legislation and regulation can reduce firearm-related suicides and homicides, as well as public demand for firearms. Among the studies cited that showed significant decreases following access restrictions through legislation were one study from New Zealand (Beautrais, Fergusson et al. 2006), two from Australia (Chapman, Alpers et al. 2006, Ozanne-Smith, Ashby et al. 2004), one from Brazil (de Souza, Macinko et al. 2007), one from Austria (Kapusta, Etzersdorfer et al. 2007), one from Colombia

(Villaveces, Cummings et al. 2000) and two from the USA (Hepburn, Azrael et al. 2006, Webster, Vernick et al. 2004).

Table XXXVIII. Interventions to limit access to guns

Beautrais et al. (2006), New Zealand	**Study design**: Interrupted time series with no comparison group	Introduction of the Amendment to the Arms Act, 1992, a more restrictive form of firearms legislation.	Data on firearm-related suicides, non-firearm-related suicides and total suicides for the years 1985 to 2002 were analysed for those aged 15 to 24 years, ≥25 years and total population aged ≥15 years.	**Mean annual rate of firearm-related suicides** Total population: –46% ($p<0.0001$) 15–24 years: –66% ($p<0.0001$) ≥25 years: –39% ($p<0.01$)
Chapman et al. (2006), Australia	**Study design**: Interrupted time series with no comparison group	1996–7 Australian Firearms Buyback and the implementation of revised, stricter gun control laws.	Data on unintentional (accidental), and intentional (suicide and homicide) deaths caused by firearms for the years 1979 to 2003 were analysed.	Significantly accelerated decrease in all firearm deaths following introduction of new laws: Post 1997 RR ratio was 3.2% (0.3% to 6.0%) lower than pre 1997.
de Fátima Marinho de Souza et al. (2007), Brazil	**Study design**: Interrupted time series with no comparison group	New gun control laws passed in October 2003. Additional measures implemented in July 2004 including a countrywide voluntary disarmament programme.	Data on deaths and hospitalisations due to firearms for 1996 to 2004 were analysed.	Decline in firearm-related mortality (8%) and firearm-related hospitalisations (4.6%) in 2004 compared to 2003 levels.
Hepburn et al. (2006), USA	**Study design**: Pooled time- series with comparison group 17 states that enacted child access prevention (CAP) laws between 1979 and 2000 were compared to non-CAP law states	Implementation of CAP laws; designed to encourage safer storage of firearms in the home.	Data on unintentional firearm deaths among children aged 0 to 14 years for 1979 to 2000 were analysed.	**Unintentional firearm deaths** (CAP states vs. non-CAP states): RR 0.78 (95% CI: 0.61 to 0.99), but the effect was largely attributed to two populous states, Florida and California, that allowed felony prosecutions. No effect was evident with these states removed from the model.
Kapusta et al. (2007), Austria	**Study design**: Interrupted time series with no comparison group	Firearm legislation reform enacted in 1997 based on European Council Directive 91/477/EEC with additional restrictions.	Data on suicides and firearm-related homicides for the years 1985 to 2005 were analysed.	Decrease in: firearm suicide rate by 4.8 % per annum (2.7% to 6.9 %); and firearm homicide rate by 9.9 % per annum (0.1 to 18.9%) following introduction of new laws

Ludwig & Cook (2000), USA	**Study design**: Interrupted time series with comparison group 32 states classified as 'treatment' states and compared with 18 'control' states with an exemption	Implementation of the Brady Handgun Violence Prevention Act in February 1994; national system of background checks and 5-day waiting periods for the purchase of handguns.	Data on firearm-related homicides and suicides for the years 1985 to 1997 were analysed.	No differences in homicide or firearm homicide rates in the 32 treatment states compared with the control states, except for a 6% decrease (2.7% to 9.3%) in firearm suicides among persons aged ≥55 years.
Ozanne-Smith et al. (2004), Victoria, Australia	**Study design**: Interrupted time series with comparison group. For the period 1988-1995 the rest of Australia was used as a control following gun legislation reform in Victoria. From 1997 to 2000 treatment and controls were reversed with the uptake of the legislation across Australia.	In Victoria, tightened restrictions on semi-automatic long arms from 1988, and Victorian Firearm Act implemented in 1996. Nationally, a firearm buyback scheme was introduced for 12 month from September 1996.	Data on unintentional firearm-related deaths, assaults, suicides and deaths of undetermined intent for 1990 to 2000 were analysed.	A significant downward trend in firearm-related deaths was measured in Victoria between 1988 and 1995 (–17.3% p<0.0001). A similar statistically significant reduction relative to Victoria was recoded in the rest of Australia following the introduction of national legislation in 1997 (–14.0%, p = 0.04).
Villaveces et al. (2000), Cali and Bogotá, Colombia	**Study design**: Interrupted time series with cross-over comparison group. Homicide rates on intervention days were compared with rates during similar days without the intervention.	Implementation of a ban on carrying firearms on weekends after a payday, on holidays, and on election days during 1993 and 1994 in Cali and from 1995 to 1997 in Bogot*á*. Checkpoints for weapon searches were set up by the police on intervention days.	Data on all homicides for 1993 to 1994 (Cali) and for 1995 to 1997 (Bogotá) were analysed.	**Firearm homicide rate** Cali: 14% lower than expected during intervention period (3% to 24%); Bogotá: 13% lower (2% to 13 %)
Webster et al. (2004), USA	**Study design**: Interrupted time series with comparison group. Compared states with and without state and federal youth-focused firearm laws and state CAP laws.	State and federal youth-focused firearm laws mandated a minimum age for the purchase or possession of handguns. CAP laws required the safe storage of firearms	Data on suicide rates for 1976 and 2001 among young people aged 14 to 20 years were analysed. Again one needs some info about the timing of the intervention.	**Total suicides (14 to 17 years / 18 to 20 years)** Federal state minimum purchase or possession age: no association CAP laws: RR 0.92 (95% CI: 0.86 to 0.98) / RR 0.89 (95% CI: 0.85 to 0.93) **Firearm suicides (14 to 17 years/ 18 to 20 years)** Federal state minimum purchase or possession age: no association CAP laws: RR 0.89 (95% CI: 0.83 to 0.96) / RR 0.87 (95% CI: 0.82 to 0.92)
ARR – adjusted rate ratio; CAP – child access prevention; CI – confidence interval; RR – rate ratio				

Source: Bellis MA, Jones L, Hughes K, Wood S. (2011). Rapid review of the current evidence base for health promotion actions for violence prevention (with specific reference to low- and middle-income countries). Prepared for the WHO Mainstreaming Health Promotion Project. Liverpool: Centre for Public Health.

Despite the disparate nature of these studies brought about by variations in the policy interventions and the availability and limitations of the routine data sources that determined study designs, there was a remarkable consistency in the direction and size of the effects of the firearm control legislation. The interventions that demonstrated the most notable population level effects were those that were applied in settings with particularly high firearm fatality rates, such as in Colombia (Villaveces et al, 2007) and Brazil (de Fátima Marinho de Souza et al., 2000), as was the case with the African and Coloured populations in this study, or that included wide-ranging restrictive measures, such as in New Zealand (Beautrais et al., 2006) and Austria (Kapustra et al., 2007), and measures to reduce firearms already in circulation, as in Australia (Chapman et al., 2006; Ozanne-Smith et al., 2004).

Although the US studies showed significant decreases, it should be noted that the child access prevention (CAP) laws evaluated by Webster et al (2004) and Hepburn et al. (2006) were less wide reaching in restricting general firearm access and also directed at a much more specific target population (i.e. children) that was already experiencing a relatively lower risk than the overall population. The outcome measures in the CAP law studies were also limited to unintentional firearm deaths, rather than firearm deaths in general. As regards the Brady Act, it should be noted that the legislation applies to the purchase of new firearms rather than those already in circulation. This, if effective, would reduce gunshot injuries arising from new guns, but would not prevent those from guns already in the wrong hands, and hence a considerable lag would be expected before a notable decrease might be observed. Yet despite the limited nature of these interventions, even the US interventions showed evidence of effectiveness.

There is only one notable challenge to the consistency of the findings discussed above that does bear mentioning, ironically a report by the United Nations Office on Drugs and Crime [UNODC] 2011) that cites South African data. The report suggests that firearm deaths have **not** declined significantly in South Africa in relation to homicides in general based on the analysis of data submitted from the South African Police Service:

> "In South Africa, homicide rates have shown a significant decrease in recent years (from over 60 per 100,000 population in 1994 to under 40 per 100,000 in 2007): a decrease related to a decline in both firearm and non-firearm homicides. During the same period, the proportion of homicides committed by firearm stayed within the range of 41 to 50 per cent of total homicides, stabilising at around 45 per cent in 2007. The homicide drop does not seem to be driven by any specific reduction in gun violence per se, rather, underlying social changes may have resulted in lower overall homicides, both by firearm and all other means". (United Nations Office on Drugs and Crime [UNODC] 2011)

However, it is difficult to ascertain the validity of this analysis, which is not described in any great detail, nor the data as the data utilised in the UNODC report are not included among the annual crime statistics released by SAPS, which only report on homicides overall without specifying the external cause of death. The SAPS murder (i.e. homicide) statistics do indeed reveal a steady year-on-year decrease from 1994 to 2011 (Table II in section 1.1 of the Introduction), but the total number of homicides is considerably lower than those estimated in the National Burden of Disease Study in 2000: 27,570 estimated by Norman et al (2007) versus 21,758 in the police statistics (Table II).

If the analysis is indeed valid then there are two possible explanations for the contradictory findings. The first is that there might have been a corresponding increase in rural gun deaths coinciding with the period in which there was a significant decrease in the major cities. However, there is no evidence to support this hypothesis. The NIMSS data for Mpumalanga (a rural province) for example, showed a decline in the percentage of firearm homicide from 20 percent in 2001(Harris 2002) to just 10 percent in 2009 (Smith 2010)

A more likely explanation may be a differential misclassification of firearm homicides in police statistics. That is, if firearm deaths have become less prone to underreporting than non-firearm deaths – with the police reliably recording all firearm deaths (or increasingly recording the firearm as a mechanism of death over time), which is consistent with a tendency to record only serious crimes - then the effect over time would be an increasing proportion of firearm deaths reflected in police murder statistics. Needless to say, without access to the source data (which are not cited in the UNODC report), and which would need to be disaggregated for the urban areas as recorded in the NIMSS in order to be comparable, it is impossible to say with any confidence whether the data were valid or whether the method of analysis was appropriate. On the basis of the findings in this thesis, which are based on more reliable data and analysis it is clear that this cannot be the case. These findings, which are consistent with the SAPS data more generally, have shown conclusively that any drop in homicide rate is solely due the implementation of the Firearm Control Act. The decrease in the homicide rate is, however, not due to more advantageous social determinants of crime, nor is it due to greater efficiency by the social response to crime (through policing and the criminal justice system), except in the implementation of the Firearm Control Act.

Specificity

Interventions that cause a singular outcome make it easier to determine causality. It is easy to determine gunshot as being the cause for those deaths in which it was a cause. This tautological relationship between gunshot as a cause and firearm mortality as the outcome confers specificity and strengthens the ability to assemble evidence, which, as shown above, is consistent with hypothesis 3. This is demonstrated in the preceding text through the legislation affecting firearm homicides exclusively and not non-firearm homicides.

Temporality

Temporality requires that the suggested cause will precede the presumed outcome if the relationship is in fact causal, i.e. there will first be exposure to the intervention (the Act) and before the outcome occurs (a subsequent decrease in firearm deaths).

A decline in firearm deaths prior to the promulgation of the Act (i.e. in 2003 as demonstrated by the analysis in this thesis) was noted and explained thus by Abrahams et al:
"The FCA came into full effect in July 2004 although aspects of it were introduced from 2001." (Abrahams, Jewkes, & Mathews, 2010)

This certainly seems to have been the case in that data from the South African Police Service Firearms Control Systems provide several indications that fewer firearms were in circulation due to stricter licensing requirements prior to 2004. For example, 142,078 new License Applications for individuals were received in 2001 and this dropped steadily year-on year to 70,679 in 2004 - a decrease of more than fifty percent. The decrease in the number of new License Applications approved was even more dramatic. In 2001, applications for 147,742 individuals were approved compared to 13,838 in 2004 – less than 10 percent of the 2001 figure.

This apparent decrease in the number of firearm licenses and firearms in circulation corresponded to the decrease in the number of firearms reported stolen during this period from 19,672 in 2001 to 16,989 in 2004 a decrease of 14 percent, which was confirmed in *The Meaning of Loss: Firearms Diversion in South Africa*, a report chapter of the Small Arms Survey 2008 Yearbook (Mthembu-Salter, Lamb 2008). The report also suggested that there had been a sharp increase in the number of weapons confiscated and recovered during the period March 2003 to April 2004 (Figure 24).

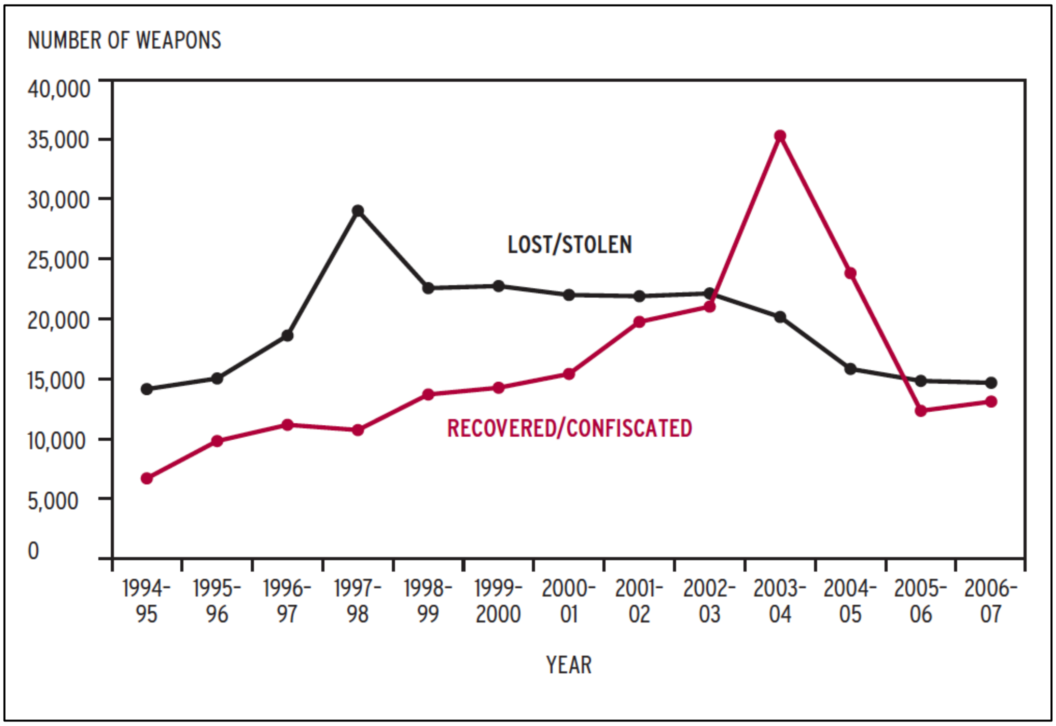

Figure 24. Civilian firearms reported lost / stolen and recovered / confiscated, 1994–2007

Source: Mthembu-Salter, Lamb 2008

Biological gradient

Evidence of a biological gradient requires an incremental change in disease rates in conjunction with corresponding changes in exposure to firearms. This is evinced in my analysis by the consistent year-on-year decline in firearm-related homicides from 2003 onwards corresponding with the apparent decline in firearm licensing described above. Although the FCA is technically a dichotomous "exposure" its effect is to continuously reduce exposure to guns over time (from 2001 onwards) as shown by the decreasing number of guns registered year-on-year.

Plausibility

Plausibility requires that the association make sense biologically. Certainly this is true of firearm control, which intuitively should lead to a reduction in firearm homicide mortality.

Experiment

Experimental research requires a demonstration that under controlled conditions changing the exposure (in this case the application of firearm control) would cause a change in the outcome (in this case gunshot injuries and deaths). As mentioned previously, this condition is not achievable as it is difficult to establish an experimental control for the application of the intervention. There is no alternative "South Africa" that could be used as a control society and gun control is not conducive to a time-limited intervention. Although there have been natural experiments such as in Colombia (Villaveces, Cummings et al. 2000), interventions of this nature typically rely on evidence of a before-after study design to assess the affect within a single society and replicability across settings as described previously.

Analogy

Analogy suggests that we are more accepting of interventions that resemble others we already accept. This is certainly the case with regard to another important industrial epidemic affecting injury rates, namely motor vehicles. We readily accept the controls that come with the licensing of motor vehicles and their drivers as mechanisms to regulate and limit aspects of their use on our roads.

Coherence

Coherence requires that a causal interpretation would fit with known facts of the natural history and biology of the condition and that the evidence all points in a common direction. Certainly a causal inference for gun control legislation does not conflict or violate alternative understandings. Indeed the advent of firearms and their circulation were necessary conditions for gun shot injury and fatality. Measures to reduce the prevalence of a necessary cause (it is not possible to suffer a gunshot wound without a firearm being present) should logically reduce the incidence of gunshots mortality.

In summary, Bradford Hill's criteria for inferring causality appear to be well satisfied for the Firearms Control Act causing a reduction in firearm deaths. As mentioned previously, there may be an as yet unknown confounding factor that explains the decline, but until this factor has been identified and its effects demonstrated, currently available research is consistent with the notion that the advent and implementation of the Act is responsible for the decline.

7.5. Utility of mortuary-based injury mortality data

It is clear from Chapter 3 that the surveillance system continues to satisfy the criteria of the CDC guidelines for surveillance systems, i.e. the following system attributes: (1) simplicity, (2) flexibility, (3) acceptability, (4) sensitivity, (5) positive predictive value and (6) the quality, timeliness, and usefulness of the data (Klaucke, Buehler et al. 1988, Klaucke, Buehler et al. 1988) and that considerable improvements have been made on the pilot system that had already been favourably evaluated in 1999 (Butchart, Peden et al. 2001). Also, the criteria for assessing the utility of surveillance systems according to Lyons et al. (2005) are comfortably satisfied by the surveillance data utilised in this thesis, i.e.: (1) measuring the burden of injuries to convey the importance of prevention to policy makers, (2) enabling comparison with other areas or countries and (3) measuring the change in the burden of injury.

In terms of the potential uses of the data, when Burrows wrote an initial report in 2001, she highlighted three potential uses of the surveillance data that had as yet not been realised, namely: 1) using the data as a basis for further research; 2) targeting prevention measures; and 3) evaluating prevention measures (Burrows 2001). The introductory chapter to this thesis has already shown how the data have been used extensively for further research and in the preceding section of this chapter (section 7.4) it has been demonstrated how the data have been used to evaluate the effectiveness of an upstream prevention measure, namely firearm control. The last remaining function, i.e. to use the data to target prevention measures, is already underway in the Western Cape using the

Provincial Injury Mortality Surveillance System (PIMSS) data, and this is discussed in more detail in section 7.7.

7.6 Data limitations

Despite the clear utility of the findings described in the previous sections of this discussion, there are certain limitations that need to be considered, which relate primarily to the representiveness of the data being collected. The data are clearly more indicative of the urban rather than the rural mortality profile and the findings of this study have shown the emergence of distinct differences across geographic locations. This is indicated by *city* being an independent predictor of homicide rates. However, as the other covariates included in the modeling remain independent predictors themselves even when the effects of *city* are taken into account, the findings suggest that the predictive relationship between homicide rates and the co-variates remains consistent despite the effect of the geographic location. . In terms of incomplete data, it was also shown that the multi-variable modeling was not sensitive to the 12 percent of data for which the age of death was missing.

It seems likely that the effect in comparing urban and rural areas might be similar to intra urban comparisons: i.e. that geographic location affects the overall homicide rate, but that the relationship between the covariates and homicide remain predictably similar. Complementary analysis that includes rural areas would confirm whether this is indeed so. Fortunately, this analysis may become possible at least in the Western Cape following the institutionalisation of a Provincial Injury Mortality Surveillance System in 2008 (Matzopoulos, Martin et al. 2010) – see section 7.7

Certainly another limitation is in the rather limited number of covariates that were available including those that might otherwise have been included if the surveillance data had been more complete. The *time of death,* the *scene of injury*, and the *blood alcohol concentration* are all routinely recorded, but were not considered reliable or complete enough for inclusion in the multi-variable analysis.

Temporal analysis in particular is problematic. The *time of death* tends to be more routinely reported, yet it is the *time of the injury event* that has more prevention utility. Yet *time of death* is not always a useful proxy, as there are many deaths due to the late effects or sequelae of injuries, and in addition the source of temporal information is often inconsistent from one facility to another, with some more reliant on information from police records and others from health services. The institutionalisation of the PIMSS may provide for training and development opportunities as well as linkages between the mortuary-based system and other services to improve the quality of these data.

With regard to the causal inference ascribed to the analysis, i.e. the FCA causes a reduction in gun homicide, Rothman (2002) contends that establishing causality is a complex and sometimes subjective process and that Hill's criteria were not initially intended to provide a checklist for causal inference. For example, the strong association between the FCA and the reduction in gun homicides may have resulted from simultaneous changes in the prevalence of other related factors and similarly the biological gradient or dose-response curve following the introduction of gun control may be a result of confounding or other biases. However, until an alternative theory is developed to explain away the impact of the FCA on gun homicides, it would seem that a causal relationship is a reasonable explanation (Rothman 2002).

The collection of reliable data on non-fatal injuries is also an important consideration in the development of evidence-led injury prevention strategy. Non fatal injuries have a considerably higher incidence and of course the opportunities that survivors provide as sources of more detailed information about injury events (Baker, O'Neill et al. 1992, Kobusingye, Lett 2000). In South Africa total non-fatal injuries treated in the public health sector were estimated at approximately 1.5 million per annum in 1999 (Matzopoulos, Prinsloo et al. 2006) compared to an estimated 60,000 injury deaths in 2000 (Norman, Matzopoulos et al. 2007). These deaths therefore represented just 4 percent of injuries requiring medical treatment in the public sector.

The proportion of injuries attributed to specific causes differs considerably for fatal and non-fatal injuries, as shown by the 1990 Cape Metropolitan Study (NTRP, 1990) and more recently by several studies in the Western Cape. For example, the PIMSS data for 2008 showed that violence accounted for 44 percent of deaths in 2008 (Smith et al), whereas a cross-sectional study of cases presenting to the Trauma Unit at Groote Schuur Hospital, a large tertiary facility, during October 2008 recorded 50 percent presenting for violence related causes (Schuurman, Cinnamon et al. 2011). Two years later in November 2010, 69 percent of the cases presenting to the Elsies River Community Health Centre in Cape Town were found to be violence-related (Govender, Matzopoulos et al. 2012). Among the violence cases, the gender profile was also dramatically different: 10 percent of the fatalities were female, compared to fourteen percent at the tertiary facility and almost 40 percent at the primary level. Although these studies differed in their respective catchment areas (a full province, half a metropolitan area and a clinic catchment comprising several suburbs of which Elsies River itself is one) and in their time periods (a full year, a full month and a period of ten days), the findings were illustrative of the importance of considering data drawn from different levels in the health care system for the setting of prevention priorities.

Certain categories of frequently occurring non-fatal injuries may be more responsive to prevention programmes than fatal injuries, and, in addition, the indirect and human value costs of severe injuries may be higher than for fatal injuries, particularly if they occur more frequently and result in permanent disabilities. For example, a study on the hospital and medical treatment costs of non-fatal firearm injuries in 2003 showed that the mean hospital cost per patient per day was US$1 467 (equivalent to R12 322[27]) more than 13-fold the annual government per capita expenditure on health, arising primarily from the hospital stay (47 percent), operating theatre costs (30 percent) and pharmaceuticals and blood products (20 percent) (Allard, Burch 2005).

[27] At the 8 June 2012 exchange rate of R8.40 : US$1.00

7.7. Opportunities for further development of the system

There are several indications that the institutionalisation of reliable injury surveillance and scientific research should be an integral part of any large-scale prevention strategy, not least the discrepancy in inferences drawn about the effect of the FCA on gun homicide drawn by UNODC based on the SAPS statistics. There is a need to integrate the various sources of injury mortality data into an all-cause injury mortality system jointly managed by research or academic institutions in collaboration with governmental and non-governmental organisations as described in section 1.2. This would be an optimal scenario to ensure that issues pertaining to data integrity are regularly interrogated and that analysis is critically reviewed before being disseminated.

There are international examples, such as in the Colombian cities of *Bogotá* and Cali where, as in the Western Cape, the high homicide rates were mainly firearm-related. The significant decline in homicide rates in *Bogotá* between 1994 and 2004 from 82 to 28 deaths per 100,000 population has been directly attributed to the institutionalisation of their prevention programme within local government agencies. Among the key success factors were the uptake of intersectoral principles in prioritising social development and cohesion, political empowerment, and investment in public infrastructure. In addition, programmatic interventions were driven by an accessible evidence base underpinned by reliable injury surveillance data and a strong partnership with academic institutions (Guerrero 2006).

Many of these success factors are already evident in the Western Cape, where the NIMSS has provided a template for the development of a Provincial Injury Mortality Surveillance System (PIMSS) providing full coverage in the Western Cape from 2008. The PIMSS provides a level of detail on the cause of injury-related deaths that was not obtainable from the existing national systems of the Department of Home Affairs and Statistics South Africa and complements the all cause mortality surveillance for the Cape Town metropolitan area that has been available at the health sub-district level since 2001(Groenewald, Bradshaw et al. 2010).

The PIMSS, developed in consultation with the provincial Forensic Pathology Service (FPS) and forensic pathologists at the Departments of Forensic Medicine at the Universities of Cape Town and Stellenbosch, included several revisions to the NIMSS upon which it is largely based, i.e.:

(1) the inclusion of a “closest police station to the death” field as well as providing for the future collection of GPS co-ordinates for the death to enable more accurate geo-spatial analysis;

(2) the inclusion of the BI1663 (i.e. the death certificate) number, which provides a unique identifier and will also enable linkage with other surveillance systems, vital registration and the population register;

(3) a revised cause, apparent manner and external cause typology, that includes an additional tier specifying natural or non-natural causes before the application of the apparent manner of death. This was intended to better distinguish whether deaths coded as being due to an ‘undetermined manner of death’ referred to deaths (a) that could not be ascribed to either natural or non-natural causes or (b) that were due to non-natural causes but where the intent could not be determined (e.g. homicide or suicide);

(4) further changes to the circumstances of injury include separate categories for (a) railway pedestrian fatalities, (b) railway passenger fatalities, which had previously been combined, and (c) bicycle fatalities and (d) motorcycle fatalities, which had also previously been combined; and

(5) the inclusion of a special interest variable to mark deaths due to e.g. gang violence, domestic violence, occupational injuries etc. that may be topical either for the purposes of research or monitoring and evaluation and might not easily be identified through the available coding.

The availability of comprehensive provincial data on an ongoing basis is likely to present numerous opportunities for further analysis. The application of the analytic techniques utilised this thesis could be applied to districts throughout the province in order to describe and compare the profile and characteristics of fatal injuries in rural compared to urban areas of the Western Cape. Linking the PIMSS data with the death certificate-based all cause mortality surveillance of the Burden of Disease project would also provide complementary data on the place of residence of the deceased , which along with the gradual refinement of PIMSS geo-spatial data on place of death, will present unique opportunities to analyse data according to socio-economic status (as place-of-residence is potentially a better proxy for SES than race), multiple deprivation indices and other Census-linked indicators.

Another important development was the commissioning of a national injury mortality study to provide a reliable, nationally representative estimate of injury mortality rates by specific cause for inclusion in the second National Burden of Disease Study for 2009. This study, which is currently underway, will be instructive in verifying whether mortality from non-natural deaths has indeed decreased nationally, as the NIMSS data were not representative of rural areas and, post 2005, were not comparable year-on-year due to the subsequent fluctuations in coverage described in section 1.4 of the Introduction (Chapter 1).

Formalising data usage arrangements

The erratic coverage by the NIMSS after 2005 highlighted the importance of consolidating partnership arrangements between research agencies and provincial and the national health departments. The Western Cape currently provides a best practice example in that the data are routinely used by the provincial government for planning and resource allocation, and prioritisation and evaluation of prevention initiatives, while researcher participation enhances the overall validity and integrity of the data, generates further analysis and interrogation of the data, and assists with the dissemination of prevention-oriented research findings. This ensures that routine surveillance utilising data from the post-mortem investigation process can be maintained and expanded. Apart from the dissemination of routine reports, the understanding among researchers involved in the project is that the data may not be distributed or used for any study or further research without approval of an institutional health research ethics committee, and the permission of the Western Cape Department of Health’s Provincial Health Research Committee

(PHRC). Table XXXIX provides a list of recent and ongoing projects approved by the Provincial Health Research Committee that have made use of the PIMSS data.

Table XXXIX. Recent and ongoing projects that have made use of the Western Cape provincial injury mortality data

Name and nature of project	Principle investigator	Status	Approval
Assessing quality of existing data sources on road traffic injuries (RTIs) and their utility in informing injury prevention in the Western Cape Province, South Africa	Linda Chohkotho	Completed	UCT MPH project Approved by UCT HREC (295/2010) and WC PHRC
The body count: using routine mortality surveillance data to drive injury prevention	Richard Matzopoulos	In progress	UCT PhD project. Approved by UCT HREC (448/2007), WCDoH and NDoH
The Influence of Temperature on Aggressive Behaviour in Cape Town	Nicole Ryan	Completed	UCT EGS (Hons) project Approved by UCT HREC (348/2011) and WC PHRC
Deaths from motor vehicle crashes attributable to alcohol-impaired driving and cost to the economy between 2002 and 2005 in South Africa	Nazia Peer	Completed	UCT Public Health Registrar project. Approved by UCT HREC(266/2009)
A national study of injury mortality in South Africa: levels and causes	Richard Matzopoulos	In progress	MRC National Burden of Disease study. Approved by MRC HREC (EC005-5/2011) and WC PHRC
Local mortality surveillance as part of the Burden of Disease Reduction Project [28]	Pam Groenewald	In progress	Commissioned by WCDoH

Improving and expanding non-fatal injury data collection efforts

The barriers to establishing a surveillance system that would provide routine information on the estimated 1.5 million injuries presenting annually just to secondary and tertiary health facilities (Matzopoulos, Prinsloo et al. 2006), are significant. For this reason, it may be preferable to establish surveillance at a selection of sentinel hospitals to inform service delivery, funding allocation and, most importantly, prevention strategies and policy formulation geared to the reduction of injuries.

There have already been several important developments to improve information about non-fatal injuries, particularly in the Western Cape. These include studies of injury caseloads at the tertiary level (Schuurman, Cinnamon et al. 2011), a precursor to the

[28] This makes use of the more accurate apparent manner and external cause of death coding available from the mortuary-based injury surveillance data.

implementation of an electronic Trauma Health Record to improve quality of care, and at the primary level to assist in the measurement of alcohol-related harms at the community level(Govender, Matzopoulos et al. 2012). Currently underway, also as part of the second National Burden of Disease study, is a retrospective review of hospital folders of injured patients presenting to Ceres Hospital, a rural secondary hospital in the Western Cape.

Integrating the use of injury surveillance data into the prevention agenda

The violence and injury prevention approach adopted in Colombia also guided strategic resource deployment to interventions that systematically targeted high-risk times, places and activities that were in turn evaluated through ongoing epidemiological monitoring for refinement and improvement (Guerrero 2006). The effectiveness of this evidence-based programme resulted in the implementation of similarly structured interventions in five other Colombian municipalities, where evaluations suggest that these too have led to significant reductions in homicide (Gutierrez-Martinez, Del Villin et al. 2007).

In the Western Cape this approach is embodied in the *High 5* project endorsed by the Provincial Cabinet that will focus efforts to reduce alcohol-related violence on five high-risk communities. It is envisaged that a set of locally-appropriate evidence-based violence prevention interventions identified from the scientific literature and through consultation with relevant experts will be implemented in these communities. Non-fatal surveillance data collected from trauma facilities serving these area (across all levels of care) will be utilised to identify key groups at risk and particular sub-locales where interventions are most needed, and also provide ongoing indicators as to the effect of these interventions.

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CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE SURVEILLANCE AND RESEARCH

There are four principal findings from this study leading to three recommendations for future action aimed at preventing the sequelae of violence and injury.

Finding 1

First among these is that the abnormally high rates of violence in South Africa do not, as evidenced by this thesis, necessarily arise from an unusual pattern of causal components, but rather from the extremely high levels of so many of the recognised risk factors for interpersonal violence and aggressive behaviour that are described in the literature review in Chapter 2. It is clear that the associations between violence and *sex* and violence and *age* explain much of the variation in homicide in addition to and independently of *race*. In the case of *race*, which in this thesis serves as a proxy for socio-economic status, it was confirmed that the widely observed associations between socio-economic status and violence were shown to be equally valid in South Africa. Calendar effects were also evident with the significant decrease in homicide by *year of death* reflecting gun control measures as well as the association between homicide and the *day of week* that in all likelihood reflects the strong association between alcohol and violence.

The confirmation that certain key risk factors for violent and aggressive behaviour identified in the literature review are indeed independent predictors of homicide in South Africa's five major cities may seem obvious at face value, but the finding is an important one. The implication of the finding is that while South Africa may have a complex mix of social and historical factors arising from our colonial and recent apartheid history, there are certain risk factors – in this case socio-economic status as operationalised by *race* in this thesis - that are universal and equally valid in our context and was, in this case, able to confirm the universal validity of socio-economic status over and above the peculiarities of South African history. The confirmation that many of the basic tenets of risks for violence and aggressive hold true in South Africa lends credence to the adoption of violence prevention approaches that have proven successful in other settings (see Finding 3).

Finding 2

The greater sophistication of analysis in this thesis compared with simpler methods used in the literature enabled a more complex understanding of the impact of important interactions between homicide fatality predictors. The analysis was able to throw light on, or dispel, a number of inaccurate findings reported in the literature employing simpler analyses of the data. It has also been possible to critically examine other popular misconceptions amongst the SAPS, government officials, and the general public, and to suggest different component cause constellations from those supporting such misconceptions and propose more accurate targets for preventive intervention. Important instances include:

- a popular misconception that Coloured people in South Africa bear a disproportionate burden of violence, which may have been influenced by the miscalculation of rates based on non-representative data;
- in addition to differences in homicide risk by *race*, which decreases with higher socio-economic status, the city of residence is a significant predictor of risk within each *race*;
- among the poor, it is unequivocally young men that are most at risk of homicide, which challenges public sentiment that inevitably foregrounds women and children as most vulnerable to violence;
- among wealthier groups it is older age groups that face increased homicide risk, suggesting criminal targeting of the vulnerable and defenceless; and
- similarly there was a higher than expected homicide risk among females in wealthier socio-economic strata, again suggesting targeting rather than random violence.

Finding 3

The third important finding of this thesis is the confirmation that it is stricter firearm control that seems to have been at the heart of the significant decrease in homicide during the study period. It is also important to note in this instance the limitations of using mortality data for evaluating interventions. It is conceivable that limiting access to lethal means, such as through gun control, may reduce the severity and lethality of violence, but not necessarily affect decrease in violent and aggressive behaviour.

Finding 4

The fourth important finding from this thesis is that there are discrepancies between homicide estimates based on the mortuary data compared to official police statistics. Most importantly there are a number of instances where interpretations of the available official statistics are at odds with the findings of this thesis. The most notable of these is the impact of gun control on homicide trends. In addition to the discrepancies between the data there are also several examples of even established researchers making incorrect inferences from the mortuary data.

> ***Recommendation 1***
>
> *The thesis provides ample evidence of the utility and need for the collection and analysis of reliable and routine data from mortuary-based surveillance systems. Such systems need to be piloted and then institutionalised within all Provincial Health Departments and the National Injury Mortality Surveillance System, which has of late fallen into some disrepair, needs to be restored. It is recommended that this expansion is based on the framework established in the Western Cape as described in section 7.7 of the Discussion (Chapter 7), which is fully institutionalised within the Forensic Pathology Service and has formalised data usage arrangements.*
>
> ***Recommendation 2***
>
> *In order to identify groups at risk, or high-risk areas, and to understand better the nature of the behavioural and interpersonal factors leading to physical violence, survivors of violence are able to provide salient information. It is imperative to expand injury surveillance activities to hospitals and other settings to improve both the quality and quantity of information on which to guide the development*

and evaluation of preventive interventions, and to ensure that resources are most effectively and efficiently allocated to effect substantial decreases in violence.

Recommendation 3

There needs to be authoratitive multisectoral and multidisciplinary oversight of the collection, analysis and reporting of surveillance data. It is recommended that any oversight function should be co-ordinated by specialists that are subject to the highest academic standards and, as in other settings, partnershis between academic institutions and government departments would ensure both sustainability and credibility.

Appendix I. Data collection form city level surveillance

NMSS DATA COLLECTION FORM

Mortuary ____________ Police No. ____________ Officer collecting body (Surname) ____________

PM no. ____________ PM Date | d | d | m | m | y | y | y | y | Pathologist (Surname) ____________

Date & Time of Injury | d | d | m | m | y | y | y | y | | h | h | Race | A | B | C | W | U | Sex | M | F | U |

Date & Time of Death | d | d | m | m | y | y | y | y | | h | h | Age: Years | | | Months | | |

Medical treatment of injury prior to death (check only ONE) | 1 None | 2 Emergency care at scene | 3 Hospitial care |

Province of injury (may differ to province of death)

1	Gauteng	7	Mpumalanga
2	W. Cape	8	Northern Province
3	K.Z. Natal	9	North West
4	E. Cape	10	Unknown
5	N. Cape	11	Other (specify) ____________
6	Free State		

Town of Injury ____________

Suburb or District ____________

Scene of injury (may differ to scene of death)

1	Private house & yard (inc. pool)	9	Medical service area
2	Residential institute	10	Industrial & construction area, mine
18	Informal settlement/squatter camp	11	Farm, primary production area
3	Bar, shebeen, N'Club, disco	12	Sea, lake, river, dam
4	Amusement park, sports area	13	Open land, beach
5	Road/street/highway	14	Countryside
6	Railway track, station	15	In custody, prison
7	Shop, bank, retail area	16	Place unknown
8	School, educational area	17	Other (specify) ____________

External Cause or Circumstance of Injury

1	Firearm Discharge	9	Fall/push/jump from height	17	Motor vehicle Driver	24	Abandoned baby
2	Sharp Object	10	Other fall/push/jump	18	Motor vehicle Unspecified	25	Electrocution
3	Blunt Object	11	Crushing	19	Railway casualty	26	Explosive blast
4	Strangulation, suffocation, asphyxia	12	Choking, aspiration	20	Bicycle, motor cycle	27	Natural cause
5	Hanging	13	Drowning, immersion	30	Aviation casualty	28	Unknown
6	Poisoning, ingestion	14	Lightning	21	Medical Procedure	29	Other Specific Cause
7	Poisoning, gassing	15	Motor vehicle Pedestrian	22	Sudden Infant Death		____________
8	Burn	16	Motor vehicle Passenger	23	Abortion, still birth		____________

Apparent Manner of Death

| 1 Homicide | 2 Suicide | 3 Accident | 4 Natural | 5 Undetermined |

Samples Taken (check all)

| 1 None | 2 Blood | 3 Tissue | 4 Other fluid |

Alcohol and Other Substances (for completion by surveillance consortium staff)

Blood Alcohol Level | | | | | Eye Fluid Alcohol | | | | | Other Substances (Specify) ____________

Appendix II. Ethics approval letter

UNIVERSITY OF CAPE TOWN

Health Sciences Faculty
Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
e-mail: preaward@curie.uct..ac.za

01 November 2007

REC REF: 448/2007

Mr RG Matzopolous
C/o Prof J Myers
Public Health & Family Medicine

Dear Mr Matzopolous

PROJECT TITLE: THE BODY COUNT: USING ROUTINE MORTALITY SURVEILLANCE DATA TO DRIVE INJURY PREVENTION

Thank you for submitting your study to the Research Ethics Committee for review.

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above mentioned study.

This serves to confirm that the University of Cape Town 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 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.

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

Please quote the REC. REF in all your correspondence.

Yours sincerely

Lesley Henley

pp **PROF M BLOCKMAN**
CHAIRPERSON, HSF HUMAN ETHICS

Appendix III. Department of Health approval letter

health

Department:
health
REPUBLIC OF SOUTH AFRICA

Private Bag X828, PRETORIA, 0001, 10TH Floor, House of Trade and Industry (HTI) Building, Cnr Prinsloo and Pretorius Street, PRETORIA, 0001 • Fedlife Building, Cnr Prinsloo and Pretorius Street, PRETORIA, 0001 • Hallmark Building, 228 Vermeulen Street, PRETORIA
Tel (012) 312 0816 Fax (012) 323 0093

Ms CC Kotzenberg Private Bag X828 PRETORIA 0001
Tel: (012) 312-0218 Fax: (012) 312-3132 E-mail: rensbag@health.gov.za

J1/15/7

Prof KC Househam
Head of Department: Health
PO Box 2060
CAPE TOWN
8000

Dear Prof Househam

SUPPORT FOR RICHARD MATZOPOULOS TO UTILIZE NIMSS DATA FOR THIS PHD STUDIES

Your letter dated 15 April 2009 has reference.

The Department of Health supports the request for Mr R Matzopoulos to use the NIMMS data for his PhD studies.

Requirements for acknowledgements, ethics, confidentiality etc. should be adhered to.

The Department wishes that Mr Matzopoulos will have a successful and fruitful study period.

Kind regards

Mrs CC Kotzenberg
Cluster Manager: Non-Communicable Diseases
Date: 17/4/09.

Appendix IV. Analysis of missing age values

To ascertain which covariates were most affected by the missing ages, the data were stratified by age into two groups: 1. Cases for which the age of the deceased was known and 2. Cases for which the age was not known. These groups were then compared to assess whether there were any meaningful discrepancies between covariates (Table A). It was clear that there was no difference between the missing and non-missing ages when stratified by *sex* or *day of week*, but there were significant differences when stratified by *race*, *city* and *year of death*.

Table A. Summary of data completeness - five cities, 2001-2005 (n= 59,065)

	Age known n (%)	Age missing n (%)
Sex		
Male	43,449 (88)	5,869 (12)
Female	8,329 (88)	1,108 (12)
Pearson chi2	*0.1921*	*p = 0.661*
Race		
Asian	1,837 (95)	91 (5)
Black	38,433 (87)	5,828 (13)
Coloured	7,719 (93)	579(7)
White	3,651 (88)	487 (12)
Pearson chi2	*354.0758*	*p < 0.01*
Day of week		
Sunday	9,991 (88)	1,364 (12)
Monday	6,382 (88)	890 (12)
Tuesday	5,413 (88)	748 (12)
Wednesday	5,250 (88)	733 (12)
Thursday	5,295 (88)	727 (12)
Friday	7,578 (88)	1,005 (12)
Saturday	12,034 (88)	1,655 (12)
Pearson chi2	*1.4964*	*p = 0.960*
City		
Cape Town	15,421 (95)	867 (5)
Durban	15,436 (99)	209 (1)
Johannesburg	11,662 (75)	3,825 (25)
Port Elizabeth	4,851 (93)	367 (7)
Pretoria	4,573 (71)	1,854 (29)
Pearson chi2	*>6600*	*p < 0.01*
Year		
2001	10,883 (85)	1,858 (15)
2002	11,193 (89)	1,399 (11)
2003	10,005 (86)	1,645 (14)
2004	9,9 (90)	1,042 (10)
2005	9,962 (89)	1,178 (11)
Pearson chi2	*223.4167*	*p < 0.01*

Further stratification of the results by *race* and *city* revealed that percentage of missing ages by *race* were only significantly different in Johannesburg, Pretoria and Port Elizabeth, whereas there was a more even distribution of missing ages by race in Cape Town and Durban. In Johannesburg, Pretoria and Port Elizabeth there were noticeably fewer white fatalities with missing age, compared to Africans in particular. This was consistent with more white fatalities having bodies identified by next of kin, compared to a lower percentage among African fatalities, as might be expected in cities with larger migrant labour force. On the other hand, stratification by *year* and *city* revealed that percentage of missing ages by *race* were significantly different in Johannesburg, Pretoria and Cape Town, whereas there was a more even distribution of missing ages by race in Durban and Port Elizabeth.

Considering then that there were significant differences in how the missing ages were distributed according to the covariates, it was important to assess their possible effect on the multivariate analysis. In order to achieve this, the final multivariate model with all covariates included except age and population, was run on three versions of the data set: (1) a data set with only known ages, (2) a data set with only missing ages and (3) the full data set with both missing and known ages (Table B). It was clear that there were significant differences in the value of certain covariates between the data set with only known-age data and the data set with only missing-age data, specifically for *race* (Asian and Coloured), *city* (Durban, Johannesburg and Pretoria), and *year* (2004).

However, it was also clear that these differences did not materially affect the values of the same coefficients in the full data set. There were no significant differences in the values of the coefficients in the full data set versus the data set with only known-age data. Consequently it can be inferred that the unusual distribution of missing ages did not have a differential effect on the final model.

Table B. Comparison of covariates in a revised model with age removed for data sets with complete and missing age data

covariates included: *sex* (categorical), *race* (categorical), *city* (categorical), *day of week* (categorical), *year of death* (categorical)			
Parameter	1. Only age- known data Coefficient (95% CI)	2. Only age- missing data Coefficient (95% CI)	3. All data Coefficient (95% CI)
Constant	0,86 (0,71:1,02)	1,29 (0,86:1,71)	0,91 (0,76:1,06)
Sex(male)	1,99 (1,92:2,06)	2,01 (1,86:2,16)	1,99 (1,92:2,06)
** Race (Asian)*	-3,48 (-3,59:-3,37)	-4,57 (-4,94:-4,2)	-3,55 (-3,66:-3,44)
** Race*	-1,66 (-1,77:-1,56)	-2,14 (-2,49:-1,8)	-1,71 (-1,81:-1,61)
Race (White)	-2,97 (-3,05:-2,89)	-3,17 (-3,39:-2,95)	-2,99 (-3,07:-2,91)
Monday	-0,53 (-0,69:-0,37)	-0,38 (-0,66:-0,1)	-0,51 (-0,67:-0,36)
Tuesday	-0,72 (-0,88:-0,56)	-0,66 (-0,95:-0,38)	-0,72 (-0,87:-0,56)
Wednesday	-0,76 (-0,92:-0,6)	-0,65 (-0,93:-0,37)	-0,75 (-0,9:-0,59)
Thursday	-0,77 (-0,93:-0,61)	-0,77 (-1,08:-0,47)	-0,77 (-0,92:-0,61)
Friday	-0,38 (-0,54:-0,22)	-0,48 (-0,76:-0,2)	-0,39 (-0,54:-0,23)
Saturday	0,17 (0,01:0,34)	0,1 (-0,18:0,39)	0,17 (0,01:0,32)
** Durban*	-0,03 (-0,16:0,1)	-1,86 (-2,28:-1,45)	-0,08 (-0,2:0,05)
** Johannesburg*	-0,35 (-0,47:-0,22)	1,25 (0,95:1,55)	-0,15 (-0,28:-0,03)
Port Elizabeth	-1,13 (-1,26:-1)	-0,93 (-1,28:-0,59)	-1,12 (-1,24:-0,99)
** Pretoria*	-1,58 (-1,71:-1,46)	0,21 (-0,11:0,53)	-1,34 (-1,47:-1,21)
2002	0,05 (-0,09:0,19)	-0,3 (-0,56:-0,05)	0,01 (-0,13:0,15)
2003	-0,07 (-0,22:0,07)	-0,31 (-0,52:-0,1)	-0,1 (-0,24:0,03)
** 2004*	-0,17 (-0,31:-0,03)	-0,77 (-0,98:-0,57)	-0,23 (-0,36:-0,1)
2005	-0,17 (-0,32:-0,02)	-0,83 (-1,06:-0,59)	-0,24 (-0,38:-0,1)

* Denotes covariates with significantly different values between (1) data set with only known-age data and (2) data set with only missing-age data.