An investigation into the profile and temporal evolution of firearm-related fatalities at Tygerberg Forensic Pathology Service Laboratory.

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Presented in fulfillment of the requirements for the degree of
Master of Medicine (MMed)
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March 2023

DECLARATION

By submitting this thesis electronically, I, Grace Amy Uren, declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Signed: Grace Amy Uren

Date: March 2023

ACKNOWLEDGEMENTS

I want to thank the following:

My supervisors: **Dr. J Verster** and **Dr. M Prinsloo,** for their guidance, encouragement, and patience.

Dr. R Matzopoulos for generously sharing his wealth of knowledge and wisdom.

Prof T Esterhuizen – Biostatistics Unit, University of Stellenbosch.

Dr B Ayele † - Biostatistics Unit, University of Stellenbosch.

Dr. K Moxley – Previously from the Registrar Research Support Office.

Mrs. AEJ Riley for her technical support.

Dr. I Mentoor for advising me on sculpting the final product to where it is today.

My friends and family for their support and understanding.

The late **Professor JJ Dempers**, Head of the Division of Forensic Medicine (13/06/1969 – 26/01/2021), who engineered this project's conception, whose legacy remains indelible on its pages.

ABBREVIATIONS

BAC	Blood alcohol concentration
DOA	Dead-on-arrival
FCA	Firearms Control Act
FMP	Forensic medical practitioner
FMPs	Forensic medical practitioners
FPL	Forensic Pathology Laboratory
FPS	Forensic Pathology Service
FRFs	Firearm-related fatalities
GSW	Gunshot wound
MLL	Medico-legal laboratory
PM	Postmortem
TBH	Tygerberg Hospital
TBFPL	Tygerberg Forensic Pathology Laboratory
ANOVA	Analysis of Variance

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PUBLICATION-READY MANUSCRIPT

The following manuscript has been prepared for submission to the Journal of Forensic and Legal Medicine.

The journal's aims, scope, and author guidelines are provided in Appendix A.

An investigation into the profile and temporal evolution of firearm-related fatalities at Tygerberg Forensic Pathology Laboratory.

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ABSTRACT

Firearm-related violence and fatalities are a significant public health and safety concern, especially in the South African City of Cape Town Metropole. Access and availability of firearms have been identified as key factors influencing this burden of firearm violence in Cape Town. Limited published data exist regarding firearm-related fatalities in the Eastern, Northern, Tygerberg, and Khayelitsha health sub-districts of the City of Cape Town Eastern Metropole serviced by the Tygerberg Mortuary. This study aimed to provide insight into the profile and severity of the pathological characteristics of firearm-related fatality cases admitted to the Tygerberg Forensic Pathology Laboratory for medicolegal postmortem examination observed in three time periods (2001, 2009, and 2017), from which patients were randomly selected. A retrospective descriptive study was conducted by evaluating autopsy case files of individuals admitted to the Tygerberg Forensic Pathology Laboratory after sustaining fatal firearm-related injuries. A total of 420 firearm-related fatality cases were included within the three distinct years, 2001 (n=125), 2009 (n=75), and 2017 (n=220), with most of these fatalities evident in young adult males. The majority of firearm-related incidents occurred in sub-economic areas and during night-time. A significant increase in the number of gunshots and individually fatal gunshot wounds sustained in victims from 2001 to 2017 (p=0.001) and 2009 to 2017 (p=0.002) was evident. The pathological severity of firearm-injury fatalities has increased and adds to the immense workload of an already overburdened facility. Interventions are required to decrease the illegal sale and distribution of firearms and stricter enforcement of gun-control legislation.

KEYWORDS

Firearm-related fatalities, Gunshot fatalities, Gunshot injuries, Firearms, Autopsy, Forensic Pathology.

HIGHLIGHTS

- Randomized selection was employed from firearm-related fatality cases admitted to Tygerberg Forensic Pathology Laboratory from 2001, 2009, and 2017, during which the Firearms Control Act and the illegal sale of state-owned guns influenced access to and availability of firearms.
- Victims of firearm violence are most commonly young adult males.
- Body regions most affected include the head, thorax, and abdomen.
- The number of gunshot wounds and individually fatal injuries sustained per victim has shown an upward trend.

INTRODUCTION

From a public health, medical and economic perspective, violence and trauma, especially firearm-related injuries, and fatalities, constitute a significant plight worldwide. Globally, more than 250 000 victims succumbed to gun-related injuries in 2019.[1] The medical and economic costs associated with firearm injuries and deaths are substantial, i.e., over 48 billion dollars in the United States between 2010 and 2012, of which 91% were attributed to fatal firearm injuries. Most costs are related to loss of income.[2] Rainio *et al.* (2015) noted that, when comparing different countries, a substantial difference can be appreciated in both the amount and nature of deaths related to firearm violence.[3] Gunshot fatalities in only six countries in 2019 accounted for almost three-quarters of cases across the globe.[1] In 2019, over sixty percent of cases in the United States were related to suicides using firearms.[1] In first-world and European countries, homicides are usually committed due to conflict in personal relationships or members of criminal groups, with few cases of armed robbery.[4] This is in contrast to low to middle income and developing countries.[4] In poverty-stricken countries like Latin America, firearm violence is exceptionally high, primarily due to the prevalence of drug trafficking and gangsterism.[4] In low to middle-income countries like South Africa, the nature and extent of firearm fatalities reflect the harsh realities of a state in which poverty, unemployment, and socio-economic instability are common. These factors contribute to a society riddled with violence. [4]

Firearm violence is a well-known and recognized problem in South Africa. A 1998 United Nations survey found that South Africa had one of the highest firearm-related homicide rates globally.[5] A rise in injuries sustained secondary to firearm-related trauma was identified from 1997 to 2000, with a national peak occurring in 2000. Across the globe, South Africa was found to have one of the highest numbers of homicide deaths in 2000, which was reported to be higher than the international average in both males and females. In the same year, gunshot fatalities accounted for 54% of homicides and 28% of unnatural deaths in South Africa.[6] Until 2003, firearms were the leading cause of homicide for all age groups from the age of 5.[6]

South African legislature enacts strict firearm control measures in the form of The Firearms Control Act (FCA) (No. 60 of 2000).[7] Provisions of this Act were incrementally rolled out over three years with a movement toward a gradual decline in civilian firearm access.[8] The FCA served to eliminate illegally-owned firearms in circulation, enforce stricter firearm licensing requirements, and tighten regulation of legally-owned guns.[7] This resulted in fewer approvals after promulgation from 2003. In the decade after the adaptation of the Act, the homicide death rate in the country de-escalated.[8] A study reviewing firearm fatalities across five cities in South Africa suggested that 4585 lives were saved from 2001 to 2005 due to the FCA.[9] Stricter gun control, mediated by the new legislation, accounted for a significant decrease in homicides overall, including firearm homicides, such that in 2011, a reduction in homicide rates of more than 60% was noted from the peak in 2000.[9]

The biggest caveat which concerns the positive association of gun control with firearm violence is that of illegal firearms. Illegal firearms are widely used in murders and other violent crimes across the country.[10] One of the significant sources of illegally owned firearms in circulation among the criminal sector in South Africa is theft or loss of private security or civilian-licensed weapons.[11] Another well documented source of firearm distribution to the gang fraternity in Cape Town was the illegal sale of state-owned weapons by a South African Police Service member to the criminal sector from as early as 2007.[11] Evidence of guns being placed with gangs suggests that gang conflicts in Cape Town escalated due to the increased supply.[11]

In 2001, almost half of the homicides in Cape Town were firearm related.[12] The suburb of Khayelitsha, located in the catchment area of the Tygerberg Forensic Pathology Laboratory (TBFPL), was identified to have the highest rates of both firearm and non-firearm homicide in the City of Cape Town metropole.[6] Matzopoulos *et al.* reviewed the homicides in Cape Town between 1994 and 2013, which reported on the prevalence of firearm fatalities compared to non-firearm homicides for the same period.[12] The research described a 13% yearly rise in the rate of homicides secondary to gunshot violence from 1994 to 2000. Alterations in the availability of firearms were found to have been associated with a rate reduction of 15% annually from 2003 to 2006. Specifically, across the cape flats, most neighbourhoods had a 100% increase in homicide rates from 2011 to 2012.[11] These results revealed a definite relationship between firearm homicides, stricter gun control and illegal firearm availability.[11]

Gunshot injuries are invariably associated with high mortality and morbidity, rarely remaining asymptomatic or manifesting late. Two features contribute to the mechanical tissue damage sustained in gunshot wound injuries, the first being destruction to the tissues in the direct path

of the missile. The second factor is the formation of a temporary cavity around the missile, which can damage structures not directly in the pathway thereof.[13] The evaluation of firearm injuries and the associated sequelae with a fatal outcome requires specialized training and expertise.[12] The rise in the proportion of firearm-related fatalities place a large burden on the service responsible for enacting such medicolegal autopsy investigations. For example, a study evaluating trends in firearm-related deaths in the Eastern Cape province of South Africa found that firearm injuries accounted for 29% of all injury-related deaths, evidenced by medicolegal autopsy findings.[5]

In the Western Cape Province of South Africa, the Forensic Pathology Service (FPS) was established in 2006 within the Department of Health. Medicolegal death investigations were previously a function of the South African Police Service. The FPS service includes 16 Forensic Pathology Facilities across the province. FPS is mandated by law to investigate all unnatural deaths.[14] Autopsy findings provide a vital indicator for profiling and assessing the magnitude of firearm-related fatalities in the areas serviced by these facilities. Autopsy findings have provided a more comprehensive mortality profile for occupational injuries, homicides, railway injuries, and road injuries as opposed to sources such as national cause of death statistics retrieved from death notification forms.[15] Despite these factors, there remains a scarcity of relevant studies evaluating the prevalence of firearm injury in South Africa as observed in medicolegal autopsy-associated data.[16]

Firearm-related fatalities are a significant public health and safety concern. This is evident in South Africa, especially the Cape Town Metropole. Limited published data exist regarding firearm-related fatalities in the Eastern, Northern, Tygerberg, and Khayelitsha health sub-districts serviced by the Tygerberg Mortuary. The primary aim of this study was to provide insight into the profile of firearm-related fatality cases admitted to the Tygerberg Forensic Pathology Laboratory (TBFPL) for medicolegal postmortem examination as observed in three cohort periods (2001, 2009, and 2017). To accomplish this aim, the first objective was to report on the demographic, geographical, temporal aspects, and postmortem blood alcohol concentrations in gunshot wound fatality cases. The second aim was to compare the severity of the pathological characteristics of injuries in these fatal cases between the three selected cohorts as documented in medicolegal postmortem autopsy reports. This would be addressed by identifying the number of gunshot wounds and fatal gunshots sustained by each victim.

METHODS

Ethical considerations

Ethics approval was obtained from the Human Research Ethics Committee of the Faculty of Medicine and Health Sciences at Stellenbosch University (S19/01/016), which also granted a waiver of informed consent due to the inherent de-identification of study subjects. The deceased individuals are allocated a unique case number upon admission to the Forensic Pathology Services facility for medicolegal autopsy. Approval for the research project was also granted by the Western Cape Department of Health. Approval was also granted to conduct the research and gain access to and utilize the autopsy data from the Western Cape Forensic Pathology Services.

Study design and setting

This is a retrospective descriptive study with a component of temporal differentiation. The City of Cape Town Metropolitan Municipality includes eight health sub-districts, namely Cape Town Eastern, Cape Town Western, Cape Town Southern, Cape Town Northern, Khayelitsha, Klipfontein, Mitchells Plain, and Tygerberg. The TBFPL is situated in the northern suburbs of Cape Town, South Africa. It is responsible for the postmortem medicolegal examination of unnatural deaths in the Khayelitsha, Northern, Eastern, and Tygerberg sub-districts. Cities/towns and suburbs within these sub-districts include Belhar, Bellville, Blackheath, Blue Downs, Brackenfell, Delft, Durbanville, Elsies River, Goodwood, Gordon's Bay, Khayelitsha, Kraaifontein, Kuils River, Lwandle, Macassar, Matroosfontein, Mfuleni, Nomzamo, Parow, Ravensmead, Sir Lowry's Pass, Somerset West, and Strand (Figure 1). Currently, the facility manages more than four thousand cases per year.

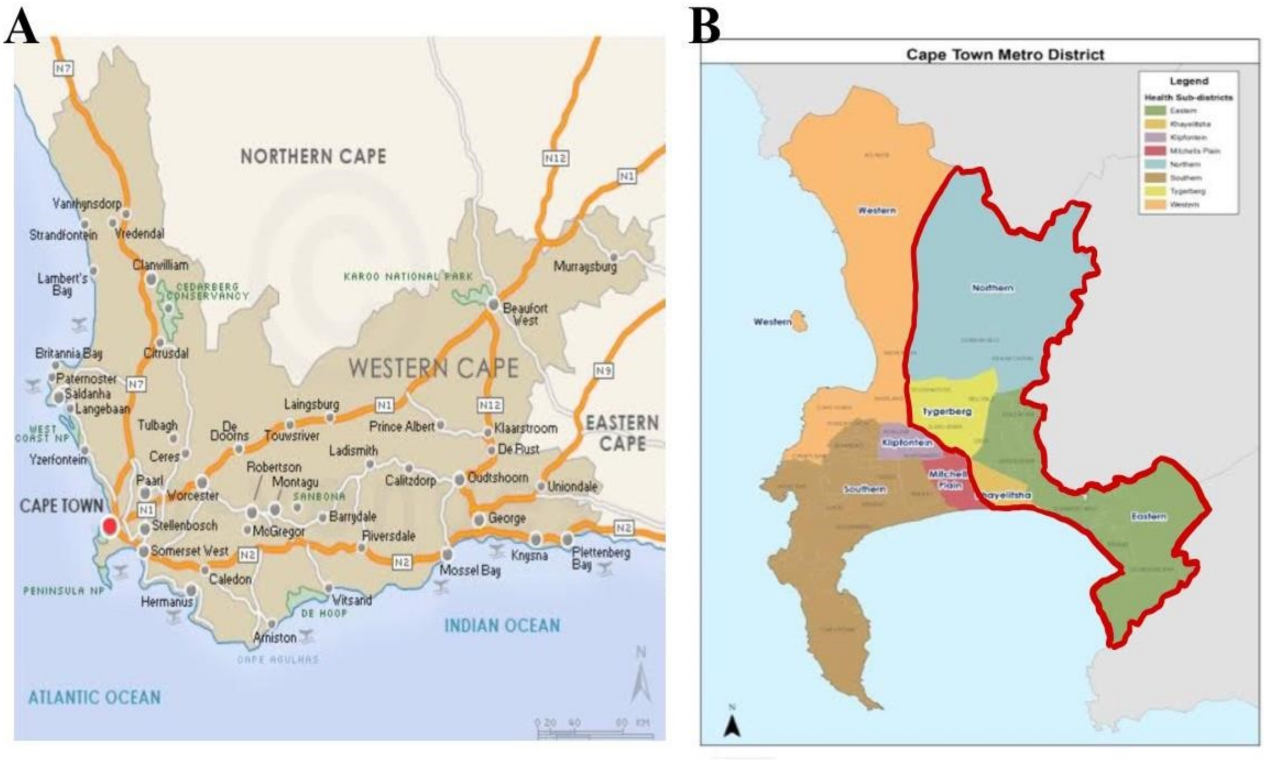

Figure 1: Figure indicating the (A) Location of the City of Cape Town's Metropole within in Western Cape province of South Africa (position indicated by a red circle)[17] and (B) the four health sub-districts of the City of Cape Town Metropole that Tygerberg Forensic Pathology Laboratory services (demarcated by a red border).[18]

This study included firearm-related case fatalities admitted to the Tygerberg Forensic Pathology Laboratory between the periods of 1 January 2001 - 31 December 2001, 1 January 2009- 31 December 2009, and 1 January 2017 - 31 December 2017 for medicolegal autopsy. The year 2001 and 2009, respectively, represent pivotal years in which the effects of firearm access and control are documented in the literature, with 2001 marking not only the year after the FCA was enacted but also when a nationwide peak in firearm-related deaths was noted. The year 2009 marked the point at which an influx of illegal, previously state-owned guns was sold to the criminal sector of Cape Town. The year 2017 was chosen as it was the last year complete medicolegal autopsy reports were available on record at the time that the study data was collected.

Sample size

In 2001, the total number of medicolegal autopsies performed at the TBFPL was 2725. Of these, 416 (15%) were firearm-related fatality cases (FRFs). In 2009 the total number of medicolegal autopsies performed at TBFPL was 2737; of these, 250 (9%) were cases of FRFs. In 2017 the total number of medicolegal autopsies performed at TBFPL was 4122; of these, 731 (17%) were cases of FRFs. (Unpublished data- obtained from FPS case registry records). Therefore, the total available sample size was 1397 FRF cases out of 9584 cases admitted in 2001, 2009, and 2017 combined.

To calculate the sample size, priority testing was used to determine the total sample size required in the 2001 and 2017 cohorts, enabling a clinically important effective sample size (ES). The aim was to achieve an ES of less than 0.5, with an ideal power of 80%. Calculations determined that an ES of 0.54 resulted in a power of 80%. A total sample size of n=420 would allow an ES of 0.152 (between small and medium effect size) to be detected at a 0.05 significance level and 80% power between three independent groups using Analysis of Variance (ANOVA) testing (or non-parametric equivalent).

Therefore, the final sample for our study included 125 cases from 2001, 75 cases from 2009, and 220 cases from 2017, respectively. Each FRF case for 2001, 2009, and 2017 was consecutively listed on a Microsoft Excel spreadsheet, and samples were then selected using a randomizing tool.[19]

Inclusion and exclusion criteria

Cases eligible for inclusion included all cases of firearm-related death admitted to the Tygerberg FPS mortuary during the periods previously described. These included adults and children, patients transported directly from the scene of the incident, those who died during transit and those who died after admission to a healthcare facility. Cases where the cause of death could not be directly attributed to firearm violence, were excluded.

Data collection

The Division of Forensic Medicine at the University of Stellenbosch, Faculty of Medicine and Health

Sciences stores data of all cases undergoing postmortem examinations at Tygerberg Forensic Pathology Laboratory (TBFPL), with hard copies of the records archived. The data is also electronically stored on the Western Cape Department of Health electronic database.

Data for 2001, 2009, and 2017 FRF study subjects were obtained by reviewing the available postmortem records. For 2001, hand-written records were retrieved from the TBFPL and compared with the complete Microsoft Excel spreadsheet case list obtained from administrative personnel at the Tygerberg FPS Division of Forensic Medicine office. Electronic archives were available for cases admitted to TBFPL in 2009 and 2017. All data was collected during the period March to September 2020.

An overview of the study methodology is provided in Figure 2. For data collection, all the study subjects were identified from the mortuary database (written records were captured in register books in 2001 and 2009, whereas electronic record keeping was performed in 2017) and were assigned a consecutive study number. Next, the postmortem examination reports were obtained to collect the necessary data. The data was manually extracted from the autopsy reports and collated into a Microsoft Excel spreadsheet stored on a password-encrypted computer and a secured cloud-hosting platform (Dropbox™). Demographic information collected for each case included the age and sex, time of day, and day of the week of death or traumatic event. The day the person was shot was used as opposed to the day the person subsequently died, which in some instances were different. Case reports were perused to identify the alleged or apparent circumstances surrounding the fatal incident. Information on health care facility history, time of survival, and medical treatment history was also collected, if applicable to a case. Postmortem reports were perused to document whether blood specimens were collected to determine alcohol concentration and the results thereof.

Moreover, each case report was further examined to identify and collate the specific gunshot wound injuries. This included the number of entrance and exit gunshot wounds, the anatomical location of the wound injuries, and the description of each gunshot wound track through the body. The gunshot wound track refers to the projectile's trajectory within the body from the point of entry. It includes all tissues and organs injured by the bullet to the exit wound or point of termination in the case of penetrating gunshot wounds. The term perforating describes projectile tracks through an object, body, or surface that exits the target again, whereas the term penetrating describes a projectile track that extends through an object, body or surface up to a point, but terminates before exiting the target again.[13] In the situation where a bullet transverses entirely through an object, the bullet has perforated the body. If the bullet enters the body without leaving it, it has penetrated it. The cause of death was captured according to the documented cause of death reported by the responsible FMP in the postmortem report.

Data analysis

Normally distributed continuous variables were summarised and presented as means ± standard deviations (SD). Non-normal data are summarised using median and interquartile range (IQR). Categorical variables are summarised using frequency counts and percentages. Chi-square testing was used to assess possible associations between outcomes and indicator variables (demographics, location, and time of incident). Analysis of Variance (ANOVA) with Kruskal-Wallis post-hoc testing was used to assess the change/difference in the number of firearm fatalities between 2001, 2009, and 2017, with the level of significance considered to be $p<0.05$. Statistical analysis was conducted with the assistance of a biostatistician from the Division of Epidemiology and Biostatistics, Stellenbosch University. Data were analyzed using STATA® version 16 statistical software.

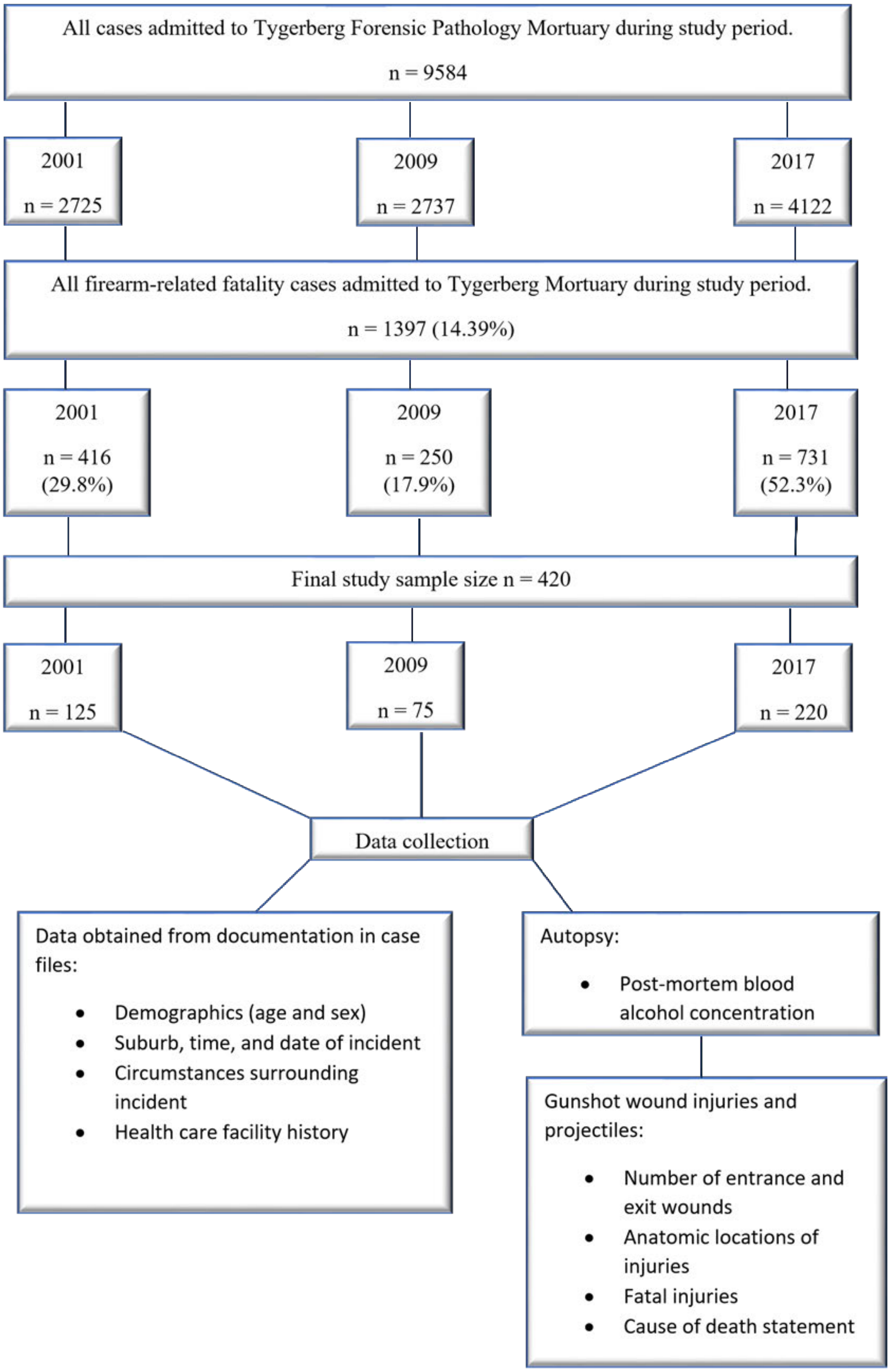

Figure 2: An overview of the study methodology

RESULTS

Demographics

Age and gender distribution

A summary of the age and gender distribution is reported in Table 1. The majority of cases in the total sample (n=420) were male (90.5%, n=380), compared to females (9.5%, n=40). The age of one male victim was unknown. The ages of the remaining 419 victims ranged between 3 years and 86 years, with a mean age of 31.1 ± 11.2 years.

Table 1: Age distribution in male and female victims across the total study sample.

	Sex		
Age group (Years)	**Male n (%)**	**Female n (%)**	**Total n (%)**
0-10	1 (0.3)	2 (5)	3 (0.7)
11-20	47 (24.4)	5 (12.5)	52 (12.4)
21-30	171 (45.1)	11 (27.5)	182 (43.4)
31-40	102 (26.9)	13 (32.5)	115 (27.4)
41-50	35 (9.2)	3 (7.5)	38 (9.1)
>50	23 (6.1)	6 (15)	29 (6.9)
Total	379*	40	419*

*The age of one male subject was unknown.

Service areas where the firearm incident occurred, as documented in the case reports

The majority of the firearm fatality incidents occurred in Khayelitsha (27.1%), followed by Delft (12.6%), Kraaifontein (9.3%), Bishop Lavis (3.6%), Bonteheuwel (3.6%), Kuils River (3.6%), Mfuleni (3.3%) and Ravensmead (3.3%). Incidents occurring in Khayelitsha, Delft, and Kraaifontein accounted for 48.9% of the total study sample. The complete data set reflecting case incidences in each suburb is depicted in Table 2.

Table 2: Suburbs in which the firearm incident took place across the total study sample.

Suburb	**Count n**	**Percent %**
Not stated	15	3.6
Belhar	9	2.1
Bellville	8	1.9
Bellville South	2	0.5
Bishop Lavis	15	3.6
Blackheath	2	0.5
Blue Downs	1	0.2
Bonteheuwel	15	3.6
Bothasig	1	0.2
Brackenfell	3	0.7
Ceres	1	0.2
Delft	53	12.6
Durbanville	2	0.5
Eerste River	10	2.4
Elsies River	30	7.1
Goodwood	3	0.7
Harare	8	1.9
Kalksteenfontein	6	1.4
Khayelitsha	114	27.1
Kleinmond	1	0.2
Kleinvlei	9	2.1
Kraaifontein	39	9.3
Kuils River	15	3.6
Langa	1	0.2
Lwandle	2	0.5
Malibu Village	1	0.2
Mfuleni	14	3.3
Montana	1	0.2
Montevideo	1	0.2
Paarl	1	0.2
Parow	5	1.2
Ravensmead	14	3.3
Richwood	1	0.2
Ruyterwacht	1	0.2
Somerset West	2	0.5
Stellenbosch	1	0.2
Strand	2	0.5
Uitsig	3	0.7
Valhalla Park	1	0.2
Wesbank	6	1.4
Worcester	1	0.2
Total	**420**	**100.0**

Day of the week and time of incident across the total study sample

Most incidents in the total study sample were found to have occurred on Sundays. Figure 3 shows the day of incident distribution across the total study sample. The reported time the incident occurred was categorized into day (7:00 am until 7:00 pm) and night (7:00 pm until 07:00 am). Of the total 420 cases in the study sample, the time of the incident was not reported in four patients. In the remaining 416 deaths, 67% (n=278) of the incidents occurred at night. Table 3 shows the time of day the incident happened across the study sample.

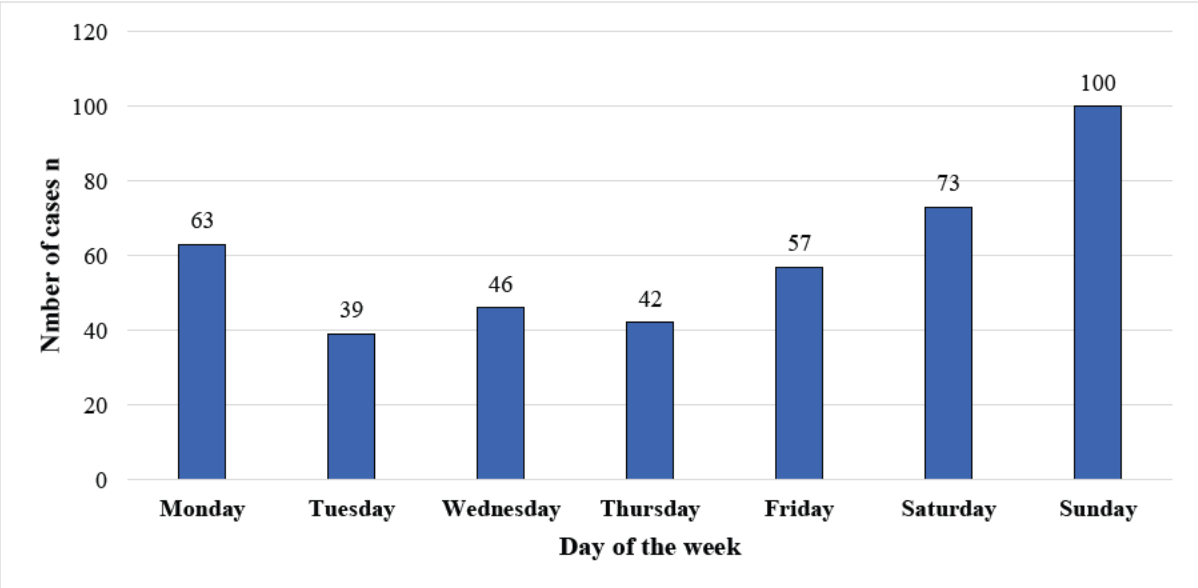

Figure 3: Day of the week the firearm incident occurred across the total study sample.

Table 3: Time of day the firearm incident occurred across the total study sample.

	Count (n)	Percent (%)	Valid percent (%)
Daytime (7 am-7 pm)	138	32.9	33.2
Night-time (7 pm - 7 am)	278	66.2	66.8
Total	**416**	**99**	**100**
Not stated	4	1	
Total	**420**	**100**	

Circumstances surrounding firearm incidents and manner of death across the total study sample

Information about the circumstances of the fatal incident from the case files and medicolegal autopsy reports was limited or absent in some cases, with only 86.1% (n=362) of cases containing an identifiable reference to the circumstances surrounding the fatal incident. Mixed reporting was also apparent in some cases, with events, alleged motive, and manner of death being referred to interchangeably, e.g., suicide, robbery, and alleged gang-related incidents being the most documented. In 95% (n=400) of the total study sample, no reference was made to the manner of death in the medicolegal autopsy report. Of the 20 cases where the manner of death was stated, ten were reported as suicide and ten as homicide. This information may not be a true reflection of the actual circumstances per the medicolegal investigation as the source thereof cannot be verified, and the outcomes of the investigations are not included in the study objectives; thus, the circumstances are not proven. Table 4 shows the alleged circumstances surrounding the firearm incident across the total study sample as documented on the scene scripts, South African Police Service A1 statements, South African Police Service 180 form, or medicolegal autopsy reports.

Table 4: Alleged circumstances surrounding the firearm incident across the total study sample as documented in the case files.

Circumstances of firearm incident:	**Count n (%)**
Not reported	362 (86.1)
Suicide	22 (5.2)
Robbery	15 (3.6)
Gang violence	9 (2.1)
Hijacking	6 (1.4)
Shot by police	6 (1.4)

Total number of gunshot wounds sustained per case

The number of entrance and exit gunshot wounds in each subject was detailed in the autopsy reports, with FMPs indicating whether each projectile perforated (entered and exited) or penetrated (entered and did not exit) the body. The number of entrance wounds noted per case directly indicates how many times each person was shot (whether the bullet exited the body or not). The number of entrance gunshot wounds sustained by subjects in the total study sample ranged between 1 and 15, with a median of 2 (IQR 1-4). Analysis of Variance with Kruskal-Wallis post-hoc testing revealed a significant increase in the median number of entrance gunshot wounds per case when comparing 2001 vs. 2017 and 2009 vs 2017, respectively ($p<0.001$). Table 5 shows the number of entrance gunshot wounds sustained by subjects in the three cohorts.

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Table 5: Number of entrance gunshot wounds sustained by subjects in each of the three cohorts.

Number of entrance gunshot wounds sustained per subject:	**Cohort**		
	2001	**2009**	**2017**
Median	1*	1**	3
25th percentile	1	1	1
75th percentile	2	3	5

*2001 vs 2017 $p<0.0001$.

**2009 vs 2017 $p<0.001$

The number of perforating gunshot wounds to the body was analyzed in each cohort. In the 2001 cohort, 125 perforating gunshot wounds were recorded, with 75 in 2009 and 217 in 2017. Analysis of Variance Kruskal-Wallis post-hoc testing revealed a significant increase in the number of exit gunshot wounds per case when comparing 2001 vs. 2017 and 2009 vs 2017, respectively ($p<0.05$). Table 6 shows the number of exit gunshot wounds noted in subjects within the three cohorts.

Table 6: Number of exit gunshot wounds noted in subjects within the three cohorts.

Number of exit gunshot wounds sustained per subject:	**Cohort**		
	2001	**2009**	**2017**
Median	1*	1**	2
25th percentile	0	1	1
75th percentile	2	2	3

*2001 vs 2017 $p<0.05$.

**2009 vs 2017 $p<0.05$.

Fatal gunshot wound tracks

An Analysis of Variance Kruskal-Wallis post-hoc test was used to compare the median number of fatal gunshot wounds between the three cohorts. No statistical significance was noted when comparing 2001 to 2009. A significant difference was detected between 2009 and 2017. ($p=0.002$) Comparative testing between 2001 and 2017 revealed a statistically significant difference in the median number of fatal gunshot wounds (p=0.001). The results are depicted in Table 7.

Table 7: Total number of fatal gunshot wounds per cohort.

Cohort		**2001**	**2009**	**2017**	**Total**
Fatal	Median	1*	1**	2	1
	Percentile 25	1	1	1	1
	Percentile 75	2	2	3	2
Non-fatal	Median	0	0	0	0
	Percentile 25	0	0	0	0
	Percentile 75	1	1	2	1

*2001 vs 2017 p=0.001

**2009 vs 2017 p=0.002.

Anatomic distribution and site of injury

The anatomical areas of the body were categorized into various regions, namely, the head, neck, upper limbs, lower limbs, thorax, abdominal, and pelvic areas. The number of fatal gunshot wounds to each region was enumerated across the total study sample, with fatal injuries resulting in catastrophic hemorrhage, vital organ injury, or acutely fatal complications of injury such as tension pneumothorax. The most common sites with fatal gunshot wounds were the head (43.8%), thorax (53.5%), and abdomen (28.1%). Table 8 shows the number of fatal gunshot wounds to the different body regions across the total study sample.

Table 8: Number of fatal gunshot wounds to different body regions.

Body Region:	**Number of fatal gunshot wounds n (%)**
Head	173 (43.8)
Neck	55 (13.3)
Thorax	213 (53.5)
Abdomen	114 (28.1)
Pelvis	35 (8.4)
Upper limbs	43 (10.4)
Lower Limbs	26 (6.3)

Final cause of death statement documented in postmortem report

Figure 4 illustrates the most common cause of death in all postmortem reports. Cause of death statements provided by the FMPs was divided into 11 categories. Gunshot wounds to the head (n=118, 28.0%) were the most common cause of death stated, followed by gunshot wounds to the chest (n=108, (25.7%), and multiple gunshot wounds to the body (n=100, 23.8%)). Isolated gunshot wounds involving the lower limbs only accounted for 1.4% of the cases (n=6), with no reports stating isolated gunshot wounds to the upper limbs as the cause of death. The cause of death statements provided by the FMP does not necessarily indicate the injuries to the organs, tissues, or specific anatomical structures (or physiological sequelae) in the body regions, but merely summarizes the area (s) in the body deemed to be affected by fatal GSW tracks.

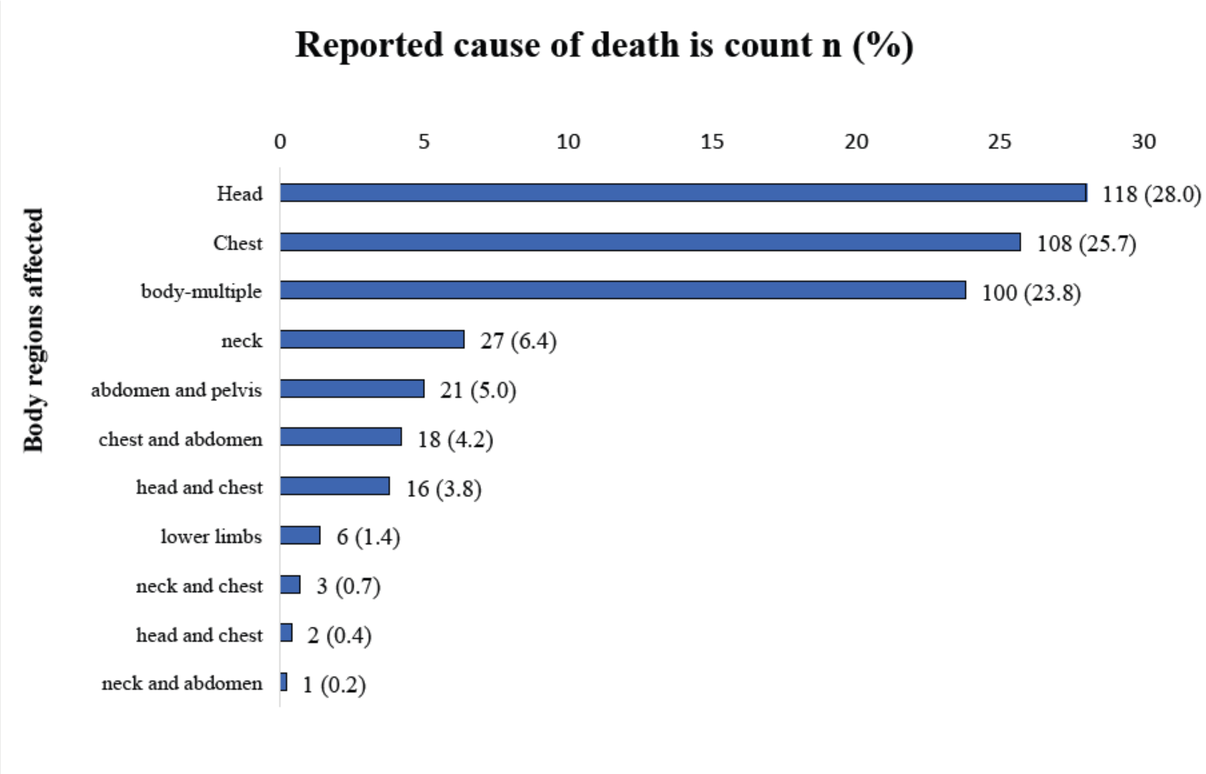

Figure 4: Cause of death as per postmortem reports.

Firearm-related fatality cases transported or admitted to healthcare facilities

A summary of healthcare facility admission and care patterns within each cohort and across the total study sample is provided in Table 9. Presentation to medical facilities for emergency care after firearm injury was not common in the study sample, with only 96 of 420 subjects admitted to a medical facility. Of these 96 cases, 54 (60%) were declared dead on arrival, and 36 (40%) demonstrated signs of life upon arrival at the facility. A Chi-square test revealed no significant difference when comparing the number of gunshot wounds sustained in subjects who showed signs of life upon admission to those who were declared dead on arrival.

The survival time frame from admission to a health care facility until death was evaluated in cases admitted for medical care. The median survival time in the hospital was 24 hours (IQR 2.6-114 hours) and ranged between 6 minutes and 40 days. No significant difference was observed in the survival time between the various cohorts. Data also demonstrated evidence of medical or surgical intervention in 28 (77.8%) cases admitted to healthcare facilities and exhibited signs of life. In the group of individuals who received medical treatment, only four received intercostal chest drains, and twenty-four underwent surgical intervention. The most common surgical intervention was a laparotomy.

Table 9: Clinical status of subjects transported to health care facilities before demise within the three cohorts and across total sample.

	Cohort			**Total sample Count n (%)**	**p-value**
	2001 Count n (%)	**2009 Count n (%)**	**2017 Count n (%)**		
Transported to health care facility:	25 (20)	17 (22.7)	54 (24.5)	96 (22.9)	
• Alive upon arrival	11 (47.2)	7 (41.2)	18 (36)	36 (40)	0.63
• Dead-on-arrival	12 (52.2)	10 (56.8)	32 (64)	54 (60)	
• Not reported	2 (8)	0 (0)	4 (7.4)	6 (6.25)	

Postmortem X-ray imaging

A summary of the number of victims on which postmortem X-rays were taken is provided in Table 10. Radiological screening at or before the autopsy procedure was conducted in 238 (43%) study subjects across the total study sample. In the 2001 cohort, X-ray imaging was performed in 3 (2.4%) cases and 23 (30%) cases within the 2009 cohort. In the 2017 cohort, X-ray imaging was performed on 179 (70%) subjects. Chi-Square testing identified a statistically significant temporal increase between the 2001 and 2009 cohorts, the 2001 and 2017 cohorts, and the 2009 and 2017 cohorts. (All $p<0.001$). No available records or references of X-ray imaging were recorded in five cases within the total sample.

Table 10: Number of cases on which X-rays were performed at the autopsy.

X-rays performed:	**Cohort**		
	2001	**2009**	**2017**
Count n (%)	3 (2.4%)	23 (30%)	179 (70%)

Post-mortem blood alcohol concentration

Figure 6 summarizes the findings concerning blood alcohol concentration results detected in samples taken at the time of the autopsy. Of the 420 cases in the study sample, 372 (83%) had a blood sample drawn at the time of the autopsy for postmortem blood alcohol concentration (BAC) determination. In five cases, no result was available. The remaining 367 cases were categorized as negative, where no alcohol was detected (BAC of 0.00g/dL), or positive, where alcohol was detected (BAC above 0.00g/dL). A total of 252 (69%) subjects out of the 367 with available results had a "negative" result, and 115 cases (31%) had "positive" blood alcohol levels. The mean BAC in the positive cases was 0.13 ± 0.08 g/dL. The range of blood alcohol concentration in the positive cases was between 0.01g/dL and 0.33g/dL. Seventy-nine of the 115 patients with a positive blood alcohol concentration (68.6%) had levels equal to or above 0.1g/dL.

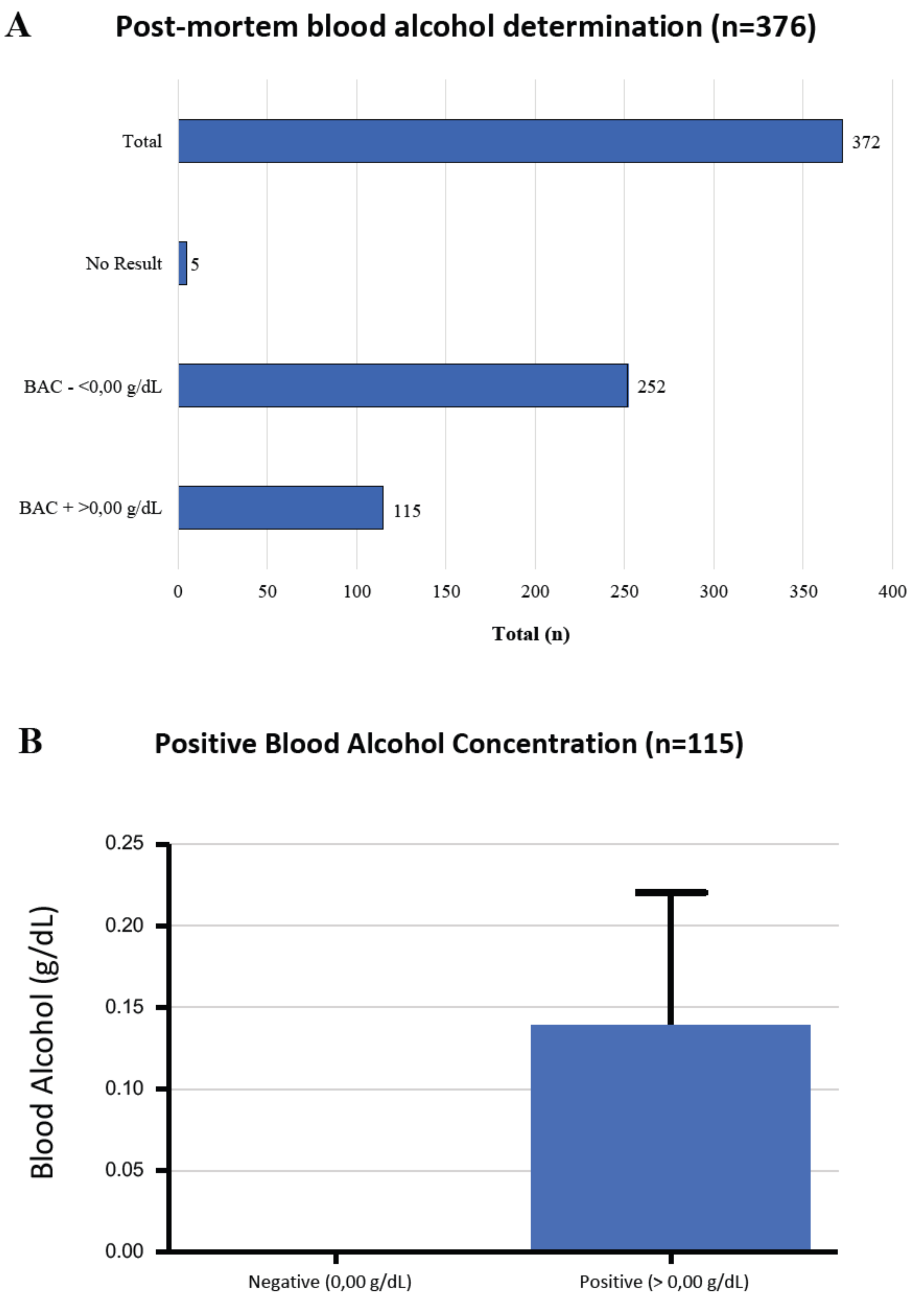

Figure 6: Figure illustrating (A) Postmortem blood alcohol concentration determination, classified as (B) negative (0.00g/dL) or positive (> 0.00g/dL).

DISCUSSION

We compared the medicolegal autopsy findings and described the demographic characteristics of FRF admitted to the Tygerberg Forensic Pathology Laboratory in Cape Town (South Africa) at three cross-sectional time points. The aim was to establish case profiles and to determine whether there has been an increase in the severity of FRF in relation to firearm access and availability.

A total of 420 FRF cases were included in this study, with the majority comprising young adult males. These findings are in agreement with other South African studies.[20 21 22] The increased risk in men may be attributed to factors such as substance use and masculine ideals.[23 22] In this study, the large majority of the firearm-fatality case incidents occurred in poverty-stricken areas with most taking place in the Suburb of Khayelitsha which has been documented in previously published literature.[6] This concurs with Metro areas more commonly experiencing challenges due to migration, rapid urbanization, and higher population density.[24] Lastly, our study re-iterated the fact that most firearm fatality deaths occur at night time.[22 21]

Moreover, this study revealed a significant increase in gunshot wound tracks to victims between the 2001 and 2017 cohorts and the 2009 and 2017 cohorts. However, no significant difference was noted in the total number of gunshot wound tracks sustained between victims in the 2001 and 2009 cohorts. The latter agrees with previous studies which have shown a decrease in firearm violence after implementing the FCA.[8,25] The results suggest an upward trend in the severity of firearm fatality cases from 2009 to 2017 and an increasing trend from 2000 to 2017. This finding may be a result of the illegal distribution of state-owned guns to the criminal sector of Cape Town starting as early as 2007.[11]

The number of fatal gunshot wounds sustained in each case shows a similar trend, with a significant increase noted between fatal individual shots sustained per person in 2017 as opposed to the 2001 cohort. This is contrasted by only a marginally significant increase between the 2009 and 2017 cohorts, with no significant difference between 2001 and 2009. The increase noted between 2001 and 2017 again emphasizes the agreement between our findings and that of other South African studies, documenting a positive association between firearm availability and gunshot-related trauma.[8,12,21,25]

In this study, most fatal gunshot wounds were sustained to the head, thorax, and abdomen. This was in agreement with a study conducted in Durban (South Africa), where gunshot wounds to the head and chest were most commonly recorded, and gunshot wounds to the trunk were associated with an increased mortality rate due to the vital structures contained in these body regions.[26] Additionally, there was a significant increase in the performance of X-ray screening in the 2017 cohort compared to the 2001 and 2009 cohorts. This corresponds to increased access and utilization of LODOX® radiographic screening in forensic medicine, a valuable tool for detecting projectiles at autopsy examination.[26]

Furthermore, the current study indicates that most gunshot injury victims died either on the scene or were declared dead on arrival at a healthcare facility. This finding supports that firearm injuries are associated with a high mortality rate and further emphasizes the enormous burden gunshot-related trauma places on healthcare facilities and the economy.[2] In contrast, no published research exists evaluating the cost of FRF on the judicial system, that of medicolegal autopsy examination, and specifically, the Tygerberg Forensic Pathology Service. Currently, no public national injury surveillance system exists in South Africa by which fatal gunshot wound injury cases can be tracked.[27] A facility-specific costing system may assist in effectively ascertaining the true cost of gunshot wound trauma on an overburdened Forensic Pathology Service. Variables such as FMP employment, specialist training and skills, time spent per autopsy, and the use of imaging modalities such as LODOX® radiological screening may be evaluated.

Most FRFs did not have alcohol detected in a postmortem blood specimen. More than two-thirds of all study subjects with positive alcohol levels had concentrations above 0.1g/dL, which is associated with motor impairment, disinhibition, and aggression.[27] An association between raised blood alcohol levels and interpersonal violence has previously been well established.[28,29] A study by Branas *et al*. in the United States found comparable results, with approximately a third of firearm-related fatality victims noted to have consumed alcohol before death.[30]

Evaluation of the medicolegal autopsy reports and mortuary case files contained minimal or no information regarding the circumstances surrounding the fatal incident and a paucity of data was documented regarding the circumstances of death in the study sample. An argument can be made for including a more extensive SAPS and FPS death scene report form. The United Nations Office on Drugs and Crime Manual for forensic pathologists suggests that a brief history of the circumstances surrounding the death be included in the content of the autopsy report itself, including who provided the information.[31] The cost-benefit impact of such an integration would first have to be evaluated as well as the possible bias and impartiality it could introduce upon the FMP performing the autopsy. According to the Inquest Act, it is not the prerogative of the FMP to report on or document findings regarding the manner of death[32], and it should not be included in the PM (postmortem) report. The primary focus of the medico-legal autopsy in our setting is to document the chief pathological findings and cause of death determination.

A limitation of this retrospective study was that not all archived case files contained all the information necessary for the study. The small sample size and the randomized selection of cases from each period inhibit generalizing the results to the population. We could not assess and analyze the trend and magnitude of firearm injury fatalities to the extent needed to draw further conclusions. We have not evaluated other contributing temporal factors such as periods of national and regional political instability, national and international economic trends, as they affect the drug trade, population migration, gang proliferation, cyclic nature of gang conflicts and taxi wars, proliferation of links with international organised crime, failure of national security and crime intelligence functions, progressive corruption in the SAPS and inefficiencies in judicial processes. To our knowledge, we are the first to report on the pathology of postmortem examination of FRF at TBFPL. Further research is recommended in this regard, especially since FRF clearly shows an upward trend, and already comprised 17% of all presumed unnatural death admissions to TBFPL in 2017. If this upward trend continues, more in-depth research is required that should also focus on the FRF burden on the healthcare system, the South African Police Service, and the judicial system. We have also obtained results that suggest significant discrepancies in three independent cohorts sampled from periods during which essential changes in firearm availability are documented.

CONCLUSION

Firearm-related fatalities admitted to the Tygerberg Forensic Pathology Laboratory have increased in severity. This field of inquiry has not previously been investigated using medicolegal autopsy report findings. The findings of this study were demonstrated by evaluating three distinct periods (2001, 2009, and 2017) historically documented as important determinants of firearm access and availability within the City of Cape Town Metropole. Legislative intervention in the form of the FCA and unlawful significantly add to the increased caseload of medicolegal autopsy examinations, especially at the Tygerberg Forensic Pathology Laboratory in South Africa. Interventions are required to decrease the illegal sale and distribution of firearms and stricter enforcement of gun-control legislation. Further research is needed regarding the cost of the autopsy examination of firearm-related deaths and the impact on the functioning and efficiency of an already understaffed and over-burdened Forensic Pathology Service.

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Acknowledgments

We thank Prof T. Esterhuizen of the biostatistics unit at the University of Stellenbosch Faculty of Health Sciences for her assistance with the statistical analysis of the data.

Dr I. Mentoor- research co-ordinator, Division of Forensic Medicine, Department of Pathology, Faculty of Health Sciences, Stellenbosch University.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or notfor-profit sectors.

Conflict of interest

The authors declare that they have no competing interests.

Appendix A – Journal guidelines

Appendix B – Ethics approval

Appendix C – Data collection tools

Appendix D- Tables and Figures