A retrospective descriptive analysis of fatal ground level falls and falls from a height: A 5-year review

By

Rumbidzai Lorraine Stephanie Chonyera
CHNLOR001

SUBMITTED TO THE UNIVERSITY OF CAPE TOWN

In partial fulfilment of the requirements for the degree

MPhil (Biomedical Forensic Science)

Faculty of Health Sciences

UNIVERSITY OF CAPE TOWN

Submission Date: 14 February 2022

Supervisors: Calvin Mole

Department of Pathology

Division of Forensic Medicine and Toxicology

University of Cape Town

Plagiarism Declaration

I, Rumbidzai Lorraine Stephanie Chonyera, hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signature: Signed by candidate

Date: 14 February 2022

Abstract

Falls have been identified as the second leading cause of accidental deaths in the world and has become a public health issue. Depending on the manner and height at which the fall occurs, different injury patterns are observed, and these are useful for the determination of circumstances surrounding death. The aim of the present study was to determine the demographic characteristics, prevalence and injury patterns associated with ground level falls and falls from a height.

A five-year (1 January 2014 - 31 December 2018) retrospective descriptive review of fatal fall cases investigated at Salt River mortuary was conducted. The prevalence and patterns of injuries were assessed with regard to fall height, impacting surface and victim demographics.

There were 360 fall related deaths. Fall prevalence in the Western Metropole District of Cape Town is 3.72/ 100 000 population. Ground level falls were prevalent among the elderly while younger individuals fell from greater heights. There is an association between the sex of an individual and height from which they fall. Accidental falls were more common and no association was found between the alleged manner of death and sex. Skeletally, a higher frequency of fractures was observed in ground level falls while the head, chest and pelvis were affected in the high level falls. additionally, an association was observed between injuries sustained and fall heights. There is a significant difference in fracture proportions between the heights in the pelvic and lower extremities and no significant difference in head, spine, chest and upper extremities.

As expected, trauma associated with falls varies based on the height of the fall. Lower extremity fractures are common in ground level falls however a challenge remains for falls from a height as there is a need for more studies to focus on the diverse patterns that occur in these.

Acknowledgements

I would like to, first of all, acknowledge my God the Almighty, who made Masters a reality, carrying me through it all. I am eternally thankful for His grace, love and light. Special thanks to my loving mom, Roswitah, for always being a pillar in my life and instilling in me the principles of hard work, discipline and perseverance. To my dedicated sister, Belindah, for always believing in me, praying with me and supporting my dream. To the rest of my family, my devoted grandparents for their unrelenting motivation.

To all my best friends Mimi and Faith, who are always there to advise me, listen and forever ready to offer a shoulder, thank you for walking this and all other journeys with me.

And finally, sincere gratitude to my wonderful supervisor Calvin G. Mole, who brought me onto a wonderful forensic experience and interesting project. For the firm and constructive feedback, helping me put all the puzzle pieces of my thoughts for the thesis together and most importantly for your unending guidance, patience and wisdom. Thank you, Calvin, **you rock!**

Table of contents

List of Abbreviations

A	-	acceleration
BAC	-	Blood Alcohol Concentration
BFT	-	Blunt force trauma
E_K	-	kinetic energy
FFH	-	Fall(s) from a height
g	-	gram
g	-	gravitational constant
GLF	-	Ground Level Fall(s)
H	-	height of fall
HBL	-	Hat Brim Line
m	-	mass
m	-	meter(s)
MVA	-	motor vehicle accident
PE	-	potential energy
s	-	stopping distance
SRM	-	Salt River Mortuary
v	-	velocity at impact
WHO	-	World Health Organisation

List of Figures

List of Tables

Chapter 2

Chapter 3

Chapter 4

1. Introduction

Globally, fall-related injuries resulted in the death of 283 000 people (WHO 2002). Two decades later they fall second to motor vehicle accident (MVA) fatalities on the unintentional injuries list, claiming approximately 684 000 lives every year with over 30 million victims sustaining non-fatal injuries (WHO 2022) an increase from the 391 000 cases seen in the early 2000s (Yoshida-Intern 2007). Fall-related deaths consistently remain in the second-place position as seen in a burden of injury study over a twenty-seven-year period (Ali *et al*., 2020). In 2018, fall fatalities were ranked ninth overall in the external causes of accidental injury deaths category in South Africa (Statistics South Africa 2015). Previously, Norman *et al*., (2007) reviewed the records for injury-associated causes of death in 2000 and reported that falls were ranked 6th in females and 7^{th} in males with 2.6% and 1.4 %, respectively.

According to the National Health Act of South Africa, the term unnatural death refers to "any death due to physical influence, direct or indirect, or related complications (b) any death, including those deaths which would normally be considered to be a death due to natural causes, which may have been the result of an act of commission or omission which may be criminal in nature; (c) any death as contemplated in section 56 of the Health Professions Act, 1974(Act No. 56 of 1974); and (d) any death which is sudden and unexpected, or unexplained, or where the cause of death is not apparent"(*National Heath Act, No. 61 of 2003, 2003: chap1*), therefore, deaths due to falls are classified as unnatural deaths. As such, in accordance with the Inquest Act of South Africa (*Inquest Act, No. 58 of 1959, 1959: s3*), fall-related deaths are subjected to medico-legal investigations to determine the circumstances and cause of death. Injuries sustained because of a fall are primarily caused by blunt force trauma. This may be as a result of impact on the surface or an intermediary object during the fall. During the investigation of a fall, it is necessary to gather information relating to the type of fall (ground level vs from a height), the height of the fall, the impacting surface, and any intermediary objects.

1.1. Fall Mechanism

The word fall is generally used to describe a drop, decrease, or decline of the subject matter from its original position, be it the economy, stocks, objects, vehicles, or a human being. The World Health Organization (WHO) describes a fall as "an event which results in a person coming to rest inadvertently on the ground or floor or other lower-level" excluding those due to self-harm, moving vehicles, and those landing in water (WHO 2022). Falls are avoidable yet they occur anywhere, from one level to another e.g., from a bed, building, staircase, mountain, playground area, or from the same level as a result of stumbling or slipping.

The classification of falls so far has been by the circumstances or height from which the fall was initiated (distance traveled from initiation to landing). Height can be further divided into ground level falls (GLF) or falls from height (FFH). The latter is categorized depending on the absences or presence of impacting objects before landing i.e., free-fall (fall due to gravitational forces only) e.g., jumping from the roof to the ground and are described as a descent from a height resulting in a direct impact with the landing surface (primary impact) or those that similarly begin from a height, land on a lower level (primary impact) and continue to the landing surface or may come into contact with other obstacles (secondary impacts) before reaching the final landing surface e.g., falling from a staircase or mountain. Ground level falls are often used to describe falls initiated from standing heights assuming the individual was initially in direct contact with the landing surface.

Fall deaths are rarely homicidal. Many authors have found them to be either accidental or suicidal. Suicidal falls require the jumper to have conscious knowledge of what they are doing while accidental falls are considered a mistake or miscalculation of actions and generally do not involve the intention to fall (Osifo *et al*., 2010) (Lapostolle *et al*.,2005) (Goren et al., 2003) (Papadakis *et al*., 2016). Granhed *et al*., (2017) combined the two categories stating that circumstances/methods from which falls may result: accidental high falls, intentional high falls and same-level falls. They further elaborated on high falls stating that the difference between the first and second categories is intention. Individuals who fall by choice/intentionally are called jumpers while fallers are individuals who accidentally/mistakenly fall.

1.2. Physics of falling

Regardless of the height or method of a fall, fall injuries are caused by the rapid decrease of the speed attained by the falling body during flight at impact known as the vertical deceleration action (Tan and Porter 2006). The transmission of force and energy into the body results in injury, the extent of which can be influenced by the impact velocity and duration of impact. These terms are defined below:

Impact velocity: the amount velocity/speed of the falling body at impact which is associated with the fall distance.

$$V = \sqrt{2gh}$$

where v= velocity at impact, g= gravitational constant of 9.8 m/s^2 and h= fall height

Potential energy: energy possessed by a body as a result of its location about the landing surface

PE = m x g x h

where m= mass, g= gravity and h= fall height

Impact energy: amount of kinetic energy (E_K) acquired by the body during descent

$E_K = 1/2\ mv^2$

where m= mass and v=velocity

Impact force: the force at impact

F = m x a

where m= mass and acceleration

Duration of impact: the period of contact between the landing surface and body

T = 2 s/v

where s= stopping distance and v= average velocity at impact

To put the above into perspective; when a fall is initiated, during flight, the falling body accumulates kinetic energy which is dependent on its mass and the speed of its descent. The greater the height of the fall the more the velocity and in turn kinetic energy attained. When the body lands, deceleration forces are involved and these have an inverse relation with the impact surface in that, the harder the landing surface the greater the impact force. The duration of impact loosely refers to the deformability or unyielding properties of the landing surface therefore the more non-deformable a surface, the shorter the impact duration will be.

A myriad of intrinsic and extrinsic factors play a role in the probability of fracture and the subsequent extent of the fracture. Intrinsic factors include risk factors such as the age of the individual, biological sex, and general health condition. For example, diabetes increases the chances of fracturing (Lu *et al*., 2013), and the presence of osteoporosis may increase the chance of a fracture occurring in women (Yoshida-Intern 2007). However, intrinsic factors do not have much of an effect on the pattern and distribution of injuries on a body, they are useful in predicting if a fracture will occur or not (Rowbotham *et al.,* 2019a). A study in Australia failed to find an association between fracture patterns as a result of falls from a height and sex (Rowbotham *et al*., 2018).

Extrinsic factors related to fractures include ignoring safety signs, shoes, home/building design. Major factors associated with the frequency and pattern of fractures include the height of fall, landing surface, manner/way fall resulted, and the landing position of the body. Alcohol and drug effects have been investigated, and findings revealed that they are indirectly associated with injury severity and patterns (ElGohary *et al*., 2016; Thierauf *et al*., 2010).

1.3. Variables that influence trauma resulting from falls

Fall Height

The patterns and distribution of injuries caused by a fall are fundamental as it not only reveals the type of trauma, mechanism causing the trauma, but also can be used to determine the height of the fall. Landing surface and the height of the fall have been recognized by many authors as determinants for the frequency and severity of injuries. The height of a fall (height between landing surface and position at which fall was initiated) is proportional to the deceleration velocity of the body during flight i.e., the greater the fall distance the greater the speed/kinetic energy generated for transfer at impact thereby producing a high frequency and severity of injuries. Similarly, the lower the fall the lesser the energy and the fewer the injuries. The landing surface is an exception to this rule and may alter findings (Lapostolle *et al*., 2005).

Surfaces (deformable or non-deformable)

The composition of the landing surface determines the time taken for energy to be absorbed from the surface to the body. Hard surfaces disperse more energy compared to softer surfaces. Injuries sustained in a fall (where no impact is made with intermediary objects) are typically a result of deceleration forces acting on the body (Tan and Porter 2006). Thus, the ability of a surface to absorb and disperse energy will play a role in the extent of injuries seen. Impacts onto deformable surfaces (such as water bodies) do not cause injuries as severe as those onto non-deformable surfaces (such as the ground). On deformable surfaces, the time taken to transfer energy from the surface to the body is longer and because of this lengthy interval the transmitted energy is reduced and fewer injuries are obtained whereas non-deformable surfaces allow for instant exchange upon contact.

Rowbotham *et al*., (2019b) assessed skeletal fracture patterns caused by falls from heights greater than three meters from a total of 95 cases and confirmed that landing on non-deformable surfaces often results in a greater number of fractures. According to Abel and Ramsey (2013), the presence of clothes, muscle tension due to intoxication, and water texture affect the distribution of trauma on soft tissue. The number of landing surfaces and obstacles encountered should also be taken into account. Primary impact is considered as the initial contact between the body and the surface, further impacts may occur subsequently as a result of the bouncing action that occurs when landing (high energy fall) or encountering obstacles e.g. rolling down a staircase or downhill making the final landing surface the secondary impact surface.

Manner of death

The method/manner by which a person falls is also important in determining if criminal proceedings need to be initiated. It is therefore important for forensic practitioners to determine whether the death was a result of an accidental, suicidal, homicidal, or an unknown method during their analysis. Fall injuries within forensics are quite difficult to interpret especially when there are no witnesses to provide testimony. Some authors suggest that the manner of fall (deliberate vs accidental) influences the landing position and subsequent appearance of injuries (Teh *et al*., 2003).

Falls from great heights are often suicidal as the victims are intentional about their deaths, they premeditate it and seek the highest accessible points to obtain their desired result while accidental falls come about unexpectedly from lower heights often used and regarded as safe. For example, in 2018, Rowbotham and associates carried out a retrospective study on skeletal trauma for falls less than three meters in height (Rowbotham *et al*., 2018a) followed by another study whose victims fell distances above three meters (Rowbotham *et al*., 2019b). Accidental falls were reported in 97% of cases in the former study while a majority of the latter study were suicidal in nature. This is supported by Petaros *et al*., (2013), who observed that suicide cases (initiated from greater heights) exhibit a greater number of injuries compared to accidental falls whose distance is often shorter. Height influences the number and frequency of injuries (Petaros *et al*., 2013).

During a fall, the body's orientation may be preserved with minor changes or it may completely change the initial orientation and take an unpredictable turn during flight. Landing can be vertical or horizontal assuming feet, buttocks, side, or headfirst impacts depending on the manner of the fall (Lapostolle *et al*., 2005). The former two impacts do not have a direct effect on the head, rather energy is transferred from the landing surface to the head through the spine. Injuries observed include brain lacerations and basal skull fractures i.e., hinge fractures and ring fractures (ring fracture surrounding the foramen magnum) (Saukko and Knight 2015). Teh *et al*., (2003), wrote that jump victims land feet-first and Christensen (2004), stated that other circumstances are more inclined to force bodies to orient horizontally. The first body component to hit the ground and the lesions caused by fall impact influence morbidity and mortality during falls from a height (Turgut *et al*., 2018). The position in which the body lands at impact is significant for the appearance of trauma on either of the surfaces.

Alcohol

Landing positions and subsequent injury patterns can be affected by alcohol. Johnston and McGovern (2004), concluded that different injury patterns are acquired depending on the presence or absence of alcohol before the fall. Craniofacial injuries were observed in individuals who had consumed alcohol while upper and lower extremity injuries were observed in individuals who had not consumed alcohol. This coincides with Honkanen and Smith (1991), who hypothesized that individuals under the influence of alcohol, unaware of their circumstances would assume any gravitational orientation passively ensuring extensive injuries to their primary impact site while conscious individuals may try to break their fall.

For individuals who are aware of their fall, two theories explain their lower/upper extremity injuries. Their reaction would be to either stretch their hands out in an oscillating motion attempting to break the fall during flight thereby opening the upper extremities up to direct impact upon landing or wrap their arms around the head to cushion themselves from a head-first impact. Comparing the finding from the two height groups in their study, it was observed that lower extremity fracturing is more prevalent in lower heights, less than 1.5 meters (Rowbotham *et al.*, 2018a).

Rationale

Studies differentiating between various mechanisms of blunt force trauma have yielded substantial results, however, once a fall has been identified as the cause of death, a challenge arises. Forensic practitioners are tasked with the responsibility of determining the circumstances surrounding death i.e., falls and their struggle is often reconstruction of events to make findings based on injury interpretation. In the absence of a reliable eye witness, the death scene and injuries are used to make conclusions and therefore, requires a strong analysis and investigation to make sure that sufficient and reliable data is available to practitioners. In addition to this, ground level falls with reference to injuries, circumstances and demographics have not been explored as adequately as falls from a height. Despite the paucity, existing knowledge rarely compares the difference in injuries sustained and where this is done, contradictions exist. In a bid to aid forensic practitioners to better understand and interpret their findings, fill the gap by adding to the existing body of knowledge and for general public health we wondered what the state of fall deaths in a medico-legal setting in South Africa was in terms of demographics, circumstances and injury patterns sustained from different heights? As such this study aimed to determine the number, pattern, and type of injuries sustained from different heights, investigate the demographics and circumstances of death in a South African context and evaluate the presence/absence of alcohol in fall victims at the time of death.

2. Literature review

Fall injuries are important to clinical medicine, forensic pathology, and forensic anthropology because of the various injuries sustained, the complexity of the patterns involved, and the different phenomena linked with them, deaths caused by falls from height are a significant topic of research (Murthy *et al*., 2012). Below is a literature review of ground level falls and falls from a height.

Great heights are associated with a lot of injuries and increase the chances of mortality (Abel and Ramsey 2013). FFH as defined above are falls originating from any position where the body is not initially in direct contact with the landing surface e.g., falling from staircases, buildings, bridges, and mountains. In a sixteen-year comparative study in France, authors Lefèvre and colleagues (2015) found that 47% of accidental fall cases were reported in staircase incidences (Lefèvre *et al*., 2015). Similarly, Preuss *et al*., (2004), analyzed one hundred and sixteen autopsy files from two forensic mortuaries in Germany and found staircase falls were common in domestic settings. Within these cases, it was found that the head sustained multiple fractures, lacerations, and bruises.

Typically, falls from a height are further, arbitrarily divided for analysis. For example, Petaros *et al*., (2013) in their study reviewing 179 fatal fall cases, grouped their height into groups of four chronologically from heights between 1.5 -3.5m, 4 – 10m,10.5 – 30m, and >30.5m. They condensed their heights into two groups for injury analysis. Smaller groups have been designed in one study to make three significant groups instead of many e.g., three to twenty-five meters, twenty-six to fifty meters, and anything greater than or equal to fifty-one meters (Rowbotham *et al*., 2019b). Freeman *et al*., (2014) and Rowbotham *et al*., (2018a) published their studies in which they grouped their fall height by making three meters the distinguishing height between low and high falls, their categories were either less than three meters and greater than or equal to three meters.

Exploration of low-level falls often includes ground level falls which distort results especially if no age restriction is placed on the inclusion criteria, the results are biased towards the elderly. This does not mean that younger individuals are not at risk of dying from low-level falls. Skull and thoracic fractures have been recorded in both ages in the height group 1.5-3m while lower extremity fractures were reported in heights less than 1.5m (Rowbotham *et al*., 2018a).

Head injuries appear to be common in all heights. Previously, research related to head injuries was focused on ways to determine the different mechanisms from which they could result. In a series of publications, Kremer and colleagues investigated the number of scalp lacerations, length of lacerations and evaluated the Hat Brim Line rule (HBL). Though the rule requires revision in terms of its definition so that it can be standardized and tested using the same features and parameters globally, authors continue to evaluate its applicability and use. In their first article published in 2008, Kremer *et al*., (2008), evaluated 80 cases, analyzing skull fractures and the number of lacerations in downstairs, ground level, and blunt force weapon cases. A review of the autopsy reports and photographs showed that the HBL rule could not be used with great certainty as fractures could be found in and above the line, however, fall cases showed a concentration of fractures in the HBL region while blow fractures were mostly concentrated above the line. In terms of lacerations, blow cases showed more lacerations while a maximum of three lacerations were recorded for falls. The authors did not observe any distinguishing features to differentiate between the two types of falls using these criteria (Kremer *et al*., 2008).

In their second paper, Kremer and Sauvageau (2009), looked at 114 cases over six years 2000 – 2005 investigating the same criteria as before. After finding that the rule was not specific, they investigated and compared the validity of the rule on lacerations and fractures, investigating the applicability of lateralization on lacerations and exploring other means that can be used to differentiate between the blows and falls. Statistically, they discovered that there is a weak correlation between the position of the laceration in relation to the HBL and the resulting circumstances and further validated their previous findings of the use of the HBL with great certainty where skull fractures are concerned, the number of lacerations and side lateralization remained uncontested. They concluded their study by formulating a criterion (combination of the three) that can be used to determine between falls or blows (Kremer and Sauvageau 2009).

Contrary to these findings, Fracasso and colleagues published a commentary article arguing that it is not definitive that fall fractures are always present above the HBL especially when the fall is initiated from a standing height, onto a flat surface without impacting on any obstacles during descent refuting the general use of this rule in all fall cases. (Fracasso *et al*., 2011).

Skull fractures were recorded in 64% of the cases, the majority of these were seen in the base of the skull (Preuss *et al*., 2004). Head, thoracic, and lower extremity skeletal regions' susceptibility to fracture injuries are related to falling heights (Rowbotham *et al*., 2018b). From their results, it was observed that 90% of their cases presented skull fractures, 66.4% to the torso with 60% presenting on the upper and lower extremities. Türk and Tsokos (2004), stated that fewer head injuries occur between 12m and 30m fall heights and suggested that it is common to find head injuries in heights below 10m and above 25m because there is a predominance of headfirst impacts due to positional change during flights. Statistically, the height of the fall correlates with the type of bone fracture. The greater the distance the more the skull shatters. When it comes to brain damage, cerebral contusions and lacerations are common in low-level heights while brain lacerations are only encountered in heights above 30meters due to the instant damage and death that occurs with no time for bleeding. At lower levels brain contusions (7-30meters) cerebral contusions occur because the impact force is lower and secondary impacts may occur (Atanasijevic *et al*., 2005).

Falls from a height as seen in most studies are more prevalent in accidental and jump-related deaths. In a population of six hundred and sixty cases, a retrospective study revealed that 56% of their cases were suicidal and the remaining were accidental. They categorized their fall heights into different categories and assessed the head injuries patterns they observed. Individuals who fell from a height of 1-7 meters had an almost similar frequency of skull fractures i.e., 43% of the cases had linear fractures while 48% had multiple fracture patterns. The frequency of multiple fractures continues to rise with an increase in height as well (Atanasijevic *et al*., 2005).

This is true for chest injuries as well; rib damage increases in falls above 3meters. It was deduced that aortic arch ruptures occur in heights no less than 4 meters and over 30% of these cases occur together with thoracic spine fractures. Severance of the heart was observed in heights above 7 meters in two locations of the heart i.e., posterior wall and the ventricular wall. (Atanasijevi *et al*., 2005).

Two reasons explain why the chest is susceptible to lesions. Injuries to the chest may be caused by the dissimilar deceleration experienced by chest organs or by its positioning and surface area, the chest is the widest part of the body that directly encounters the landing surface (Rowbotham *et al*., 2019b). However, when interpreting these injuries, it is important to consider BFT injuries caused by resuscitation. Abel and Ramsey (2013), labeled rib fractures as the "hallmark" of water suicides cases after they analyzed 29 coroner files for witnessed suicide jumpers from a bridge in South Carolina between 1990-2011. They observed an equal distribution of fractures on both sides of the ribs following impact with soft surfaces i.e., water in contrast to Teh *et al*., (2003) who reported a right-side dominance.

According to Rowbotham and Blau (2016), fracturing of the ribs and pelvis is found predominantly in high-energy falls. In a subsequent study Rowbotham *et al*., (2019b) reiterated that rib fractures are caused by heights as over 90% of her cases exhibited thoracic fractures. Similar results were reported by Bruno *et al*., (2014). In a retrospective series including 747 cases where the number of rib fractures produced between different mechanisms such as MVA's and assaults was analyzed, Dragu *et al*., (2009), reported that fractures in falls from a height start at a minimum of 4 rib fractures to anything over thirty fractures as the number of rib fractures corresponds to the force exerted during impact. After analyzing 179 free fall cases, Petaros *et al*., (2013), also reported that chest fractures increased with greater heights. Their results showed that cases reported from heights ranging up to ten meters presented with unilateral thoracic fractures while greater heights produced bilateral fractures.

Pelvic fractures are commonly found in polytrauma cases in association with damage to other regional skeletal fractures. Generally, the pelvis requires a great deal of energy to fracture (Petaros *et al*., 2013). This is true as seen in the results from an epidemiological study in Singapore analyzing pelvic fractures, were authors noted that high falls constituted 44% of their cases over a five-year period, respectively (Ooi *et al*., 2010). It is rare for fractures in this location to directly result in death, however, tearing of surrounding tissue and blood vessels such as the iliac and femoral vessels can cause hemorrhage and subsequent death. One-sided pelvic fractures were observed more frequently than bilateral fractures in greater heights while pubic fractures appeared equally in the 1.5 – 10m and >10m heights (Petaros *et al*., 2013). An assessment of fractures resulting from heights greater than 3m by Rowbotham *et al*., (2019a) revealed that 82% of the cases in their study presented with lumbar vertebrae and pelvic girdle fractures. These fractures are possibly due to the high energy transfer during direct impact or indirect force from the axial region. Secondary impacts i.e., several landing positions ensure that either one or both impacts affect this region. Intoxication has also been included as it can alter an individual's reactivity and landing position. Injuries from this region, however, cannot be used to assume landing position without further information, as more conscious individuals may attempt to maneuver during falling and subsequently land feet first, while intoxicated individuals often land horizontally, in both cases the pelvis is susceptible.

Freeman *et al*., (2014) investigated head and neck injury patterns in falls from a height with a focus on the epidemiology and biomechanics in Sweden. They found 820 skull fractures and 182 cervical spine fractures in their study. Compared to other regions of the vertebrae, the cervical spine appears to be the most vulnerable region of the entire vertebrae. This contradicts Bruno *et al*., (2014) who observed a greater number of thoracic spine fractures. Petaros *et al*., (2013) reported that compared to the lumbar spine, they observed a predominance of cervical and thoracic fractures. In the same research, an evaluation of fractures sustained from two height groups (1-10m and 10.5-30m), Petaros *et al*., (2013) revealed that the frequency of bilateral fractures increases with height while an increase in unilateral fractures is observed with a decrease in height. This is attributed to the amount of kinetic energy generated.

Generally, GLFs also known as same-level falls i.e., landing onto a surface that was previously in contact with a part of the body prior to falling (Granhed *et al*., 2017). Compared to falls from a height, ground level falls are low velocity falls and are considered to cause fewer injuries compared to the latter. Commonly, ground level falls are accidental because of the distance of the fall, GLFs often cause minor/negligible injuries such that most falls are not reported. However, numerous studies Chisholm and Harruff 2010; Bhattacharya *et al*., 2016; Yokota *et al*., 2020; Deprey *et al*., 2017 and Galet *et al*., 2018 have found old age to be a predictor of significant injury in GLFs. Considering the increased risk of GLFs amongst the elderly, research surrounding ground level falls has predominantly focussed on this population.

Jamebozorgi *et al*., (2013) investigated the prevalence of falls in the elderly and recognized that fall mechanisms recorded included, bed falls (rolling out or while getting out of bed), those resulting from a sprained ankle, stumbling and slipping. This is in keeping with the findings of Formiga *et al*., (2008) whose study included approximately 70% of GLFs occurring indoors. Falls from less than one-meter result in trauma to the extremities while combined regions showed trauma at greater distances (ElGohary *et al*., 2016). Femur fractures are largely reported in older population fall studies where intrinsic factors play more of a role compared to extrinsic factors (Jamebozorgi *et al*., 2013). Age-related changes in health and bone result in fall fractures and death amongst the elderly (Rowbotham *et al*., 2018a).

Atanasijevic *et al*., (2005) reported that 95 out of 98 of their GLF cases showed head injuries in the form of linear fractures, subdural hemorrhages, and brain contusions. Their results show two different trends between cases with head injuries and those without. Head injuries were more common in GLF (Türk and Tsokos 2004). In addition to slipping and stumbling, loss of balance due to intoxication is also known to cause backward falls which result in injuries to the occipital areas (Thierauf *et al*., 2010).

Table 2. 1: Prevalence of injury to each body region as seen in the literature.

Injury Region	Ground Level Falls	Falls from a height
Head	(Atanasijevic *et al*., 2005): 96% of GLF cases, (Thierauf *et al*., 2010): 47.5% of cases.	(Bruno *et al*., 2014): 70% of cases, Preuss *et al*., (2004): 65% of cases, (Rowbotham *et al*., 2019a): 12,7% of cases
Vertebral column		(Petaros *et al*., 2013): 40% of cases, (Freeman *et al*., 2014): 21% of cases,
Chest	(Yokota et al., 2020): 11% of cases	(Atanasijevic *et al*., 2009): 66% of cases, (Rowbotham *et al*.,

		2019a): 8.8% of cases (Petaros *et al*., 2013): 73% of cases, (Abel and Ramsey 2013): 26% of cases,
Upper extremities		(Petaros *et al*., 2013): 32% of cases, (Rowbotham et al., 2019a): 25.7% of cases
Pelvic region	(Yokota et al., 2020): 18% of cases	(Petaros *et al*., 2013): 28% of cases, (Rowbotham et al., 2019a): 12.1% of cases
Lower extremities	(Martuchi *et al*., 2020): 35% of cases, (Yokota *et al*., 2020): 6.1% of cases	(Petaros *et al*., 2013): 37% of cases, (Rowbotham *et al*., 2019a): 28% of cases.

Conclusion

Falls are avoidable but continue to claim a lot of lives annually. Deaths resulting from falls are considered unnatural and therefore are subject to medico-legal investigations. Injury patterns displayed on human remains may reveal the height, primary impact region, and manner in which the fall occurred. Identifying the actual or most likely anatomical place of primary impact can aid in the reconstruction of events and the assessment of circumstances surrounding death, especially for forensic practitioners who are tasked with the analysis of skeletonized or differently preserved human remains. There is a paucity of fall-related studies in a medicolegal context in South Africa, which led to the investigation of fall-related deaths in terms of the demographic characteristics, prevalence, and injury patterns associated with ground level falls and falls from a height. The main objectives were to determine the number, pattern, and type of injuries sustained from different heights, investigate the circumstances of death and evaluate the presence/absence of alcohol in fall victims at the time of death.

3. Methodology

3.1. Study Approach

This study is a retrospective descriptive analysis of fall cases admitted to Salt River mortuary (SRM), Cape Town within a five-year period (1 January 2014 – 31 December 2018). SRM is an academic medico-legal laboratory servicing the Western metropole of the City of Cape Town, conducting more than 3 000 autopsies per year (Clark *et al.*, 2017).

3.2. Case Identification

All cases where the cause of death was related to a fall were included. Cases whose fall occurred within one year of death and was directly related to the cause/etiology of death were included irrespective of the suspected manner of death. Cases, where the fall was not directly related to the cause of death, were excluded, for example where a fall occurred as a result of natural diseases. Furthermore, cases, where an individual fell from a moving vehicle, were excluded as these are classified as motor vehicle accidents.

3.3. Data Collection

To fulfill the aim and objectives of this study, a review of all fall cases during the period (1 January 2014 – 31 December 2018) was carried out. Cases were identified on the Division of Forensic Medicine and Toxicology UCT office autopsy database (HREC REF: R036/2014). Following this assessment, case files comprising post-mortem reports, ancillary tests results, scene reports, and any other relevant notes depending on the nature of the death were assessed.

The following information (figure 3.1) was collected from each case file and extracted onto a Microsoft® Office Excel® spreadsheet and transferred to SPSS IBM statistics 27 for statistical analysis:

Table 3. 1: Variables associated with the characteristics of fatal falls

Variable	Type	Option
Age	Numerical continuous	Age at the time of death in years
Sex	Categorical, Binary	The biological sex of the individual
Geographical Location	Categorical, Nominal	Area (suburb) in which fall occurred
Site of fall	Categorical	Place where the fall occurred
Height of the fall	Categorical, Binary	Distance between the landing surface and the height from the fall was initiated.
Landing Surface	Categorical Binary	Hard(H), Soft (S), Unknown
Type of Injury	Categorical, Nominal	Fall-related injuries sustained by the individual
Location of injury (body region)	Categorical, Nominal	Head, Chest, Upper extremity, Pelvic, Abdominal, Vertebral/spinal, Lower extremity
Number of Injured body regions	Numerical, Discrete	Total number of injured body regions on one person
Sample collected for blood alcohol concentration analysis	Categorical, Binary	Indicates whether or not the pathologist collected samples for blood alcohol concentration analysis
Presence of alcohol in the victim	Categorical,	Yes (Y), No (N), Unavailable (U)
Cause of death	Categorical	The event that set-in motion a chain of circumstances that culminated in death.
Survival period	Numerical	Number of days survived after fall prior to death
Scene of death	Categorical	Died on the scene, died on arrival at the hospital, died after hospitalization
Suspected manner of death	Categorical	The circumstances which initiated the fall and subsequent death.

3.4. Data analysis

Prevalence of fall-related deaths was considered in terms of the percentage of total autopsies conducted as well as calculated per 100 000 population in the service area of SRM. The population for this region was calculated using 2011 census data for each suburb published by the City of Cape Town (Statistics South Africa, 2012).

For the assessment of the skeletal and soft tissue trauma, the body was divided into anatomical regions as follows:

Table 3. 2: Shows skeletal bones grouped into an anatomical region

Skeletal Region	**Skeletal Bones**
Head	Frontal, occipital, temporal, parietal, hyoid, maxilla, mandible, nasal and facial bones
Chest	Ribs, clavicles, scapula, shoulder, sternum
Upper-limb/extremities	Humerus, ulna, radius, wrist bones, metacarpals
Vertebra	Cervical, thoracic, and lumbar
Pelvis	Pelvic bones and sacrum
Lower-limb/extremities	Femur, tibia, fibula, knee, metatarsals

Table 3. 3: Shows soft tissue organs/structures grouped into anatomical region

Soft Tissue Region	**Soft tissue organs**
Head	cerebral, cerebellum brainstem and related structures

Chest	intercoastal muscles, lungs, descending thoracic aorta, heart, and associated components
Abdomen	all abdominal structures and pelvic structures

Geographic data was visualized and presented using tableau software (Tableau 2021.4).

Descriptive statistics were used to identify the presence of patterns and commonalities for each characteristic. The Chi-square test was used to ascertain differences between categorical variables and Z-tests of proportion were carried out to determine the injury proportions for each region in between the two heights. All statistical analysis was conducted using SPSS IBM statistics 27.

3.5. Ethics

Ethical approval for this study was granted by the Human Research Ethics Committee (HREC) of the Faculty of Health Sciences at the University of Cape Town (HREC REF: 153/2021). Permission to access the office autopsy database and collect information from case records was granted from the Head of the Division of Forensic Medicine and Toxicology (Professor L Martin).

4. Results

4.1. Prevalence of fall-related deaths

A total of 18 744 autopsies were conducted during January 2014 to December 2018 at the SRM. During the period of study, 360 fall-related cases were admitted at the SRM, accounting for 1.92% of the total autopsies conducted over the period (table 1). No significant difference was seen in the distribution of fall fatalities between the five years (p=0.655). The prevalence of fatal falls during this five-year period was 3.72/100 000 population/ year.

During the investigation of these cases, the exact height of the fall was only recorded in 101 (28%) cases. However, in 235 (65%) cases the height of the fall could be broadly classified as falls from a height or ground level falls. The height of the fall was not classified in 125 (35%) cases. In the remaining cases where the height of the fall could be classified, 48% (n=171) were from a height and 18% (n=64) of cases were from a ground level.

Table 4. 1: Distribution of fall fatalities and total autopsies conducted at the SRM per year (2014-2018)

Year	**Total autopsies per year** **N**	**Fall fatalities per year** **n (% autopsies)**	**Prevalence fatal falls** **(/100 000 population)**
2014	3461	79 (2.28%)	4.08
2015	3695	63 (1.71%)	3.25
2016	3660	71 (1.94%)	3.66
2017	3885	78 (2.00%)	4.03
2018	4043	69 (1.70%)	3.56
Total	**18744**	**360 (1.92%)**	**3.72**

4.2. Demographic distribution of fall-related deaths

4.2.1 Age

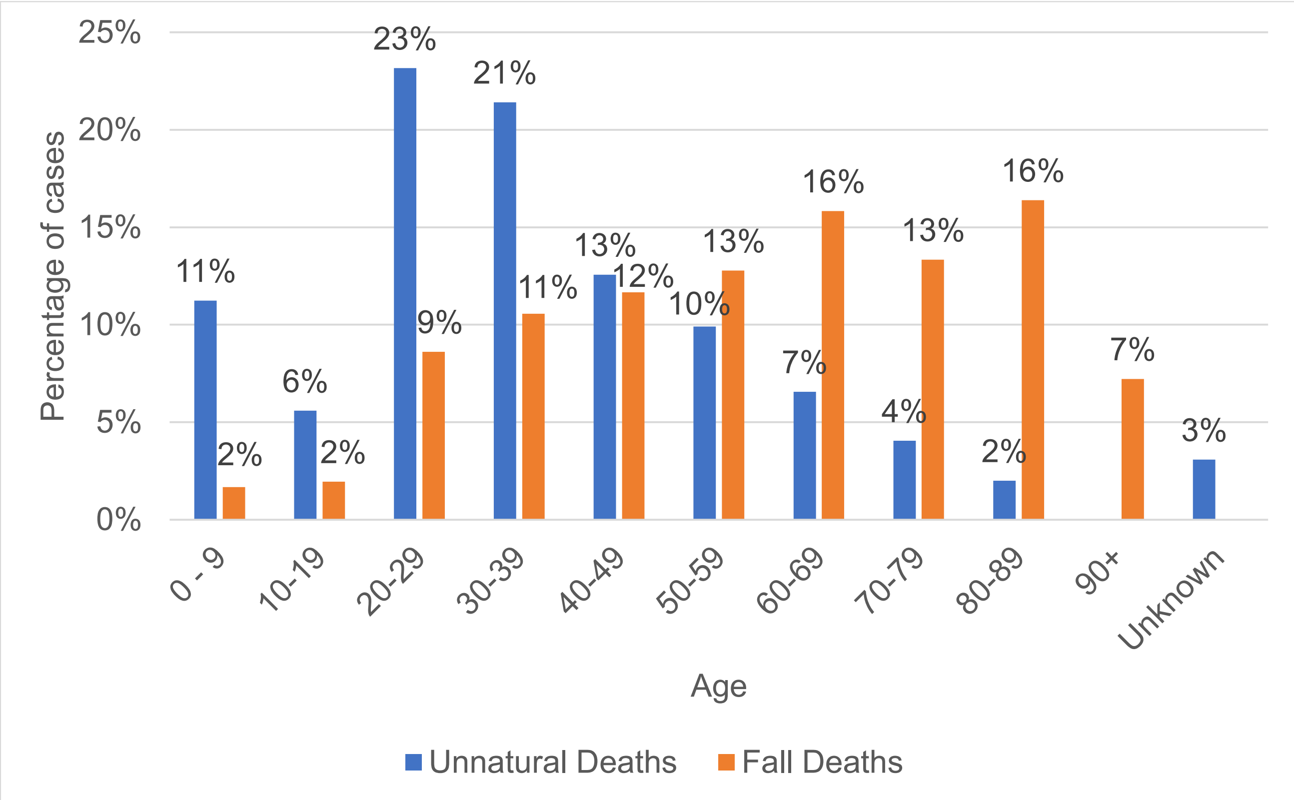

Figure 4. 1: Percentage age distribution of unnatural death and fall victims from 2014 to 2018 at SRM.

The minimum age of included individuals in this study was four months old and the maximum age was 104-year-old. The mean age of fall victims in this study was 59.99 years with a standard deviation of 22.8 years. The age distribution of fatal falls cases at SRM during the period of study is shown in Figure 4.1. The relative risk of fatal falls was determined in comparison to the total distribution of unnatural deaths investigated at SRM. The highest percentage of fall victims in this study were found in the age groups 60 to 69 years (16%; n=57) and 80 to 89 years (16%; n=59) with a similar percentage distribution in the number of cases. This was followed by the age groups 50 to 59 (n=46) and 70 to 79-year (n=48) age groups each contributing 13% to the total. In terms of unnatural deaths, the elderly are at a greater risk of fall-related deaths.

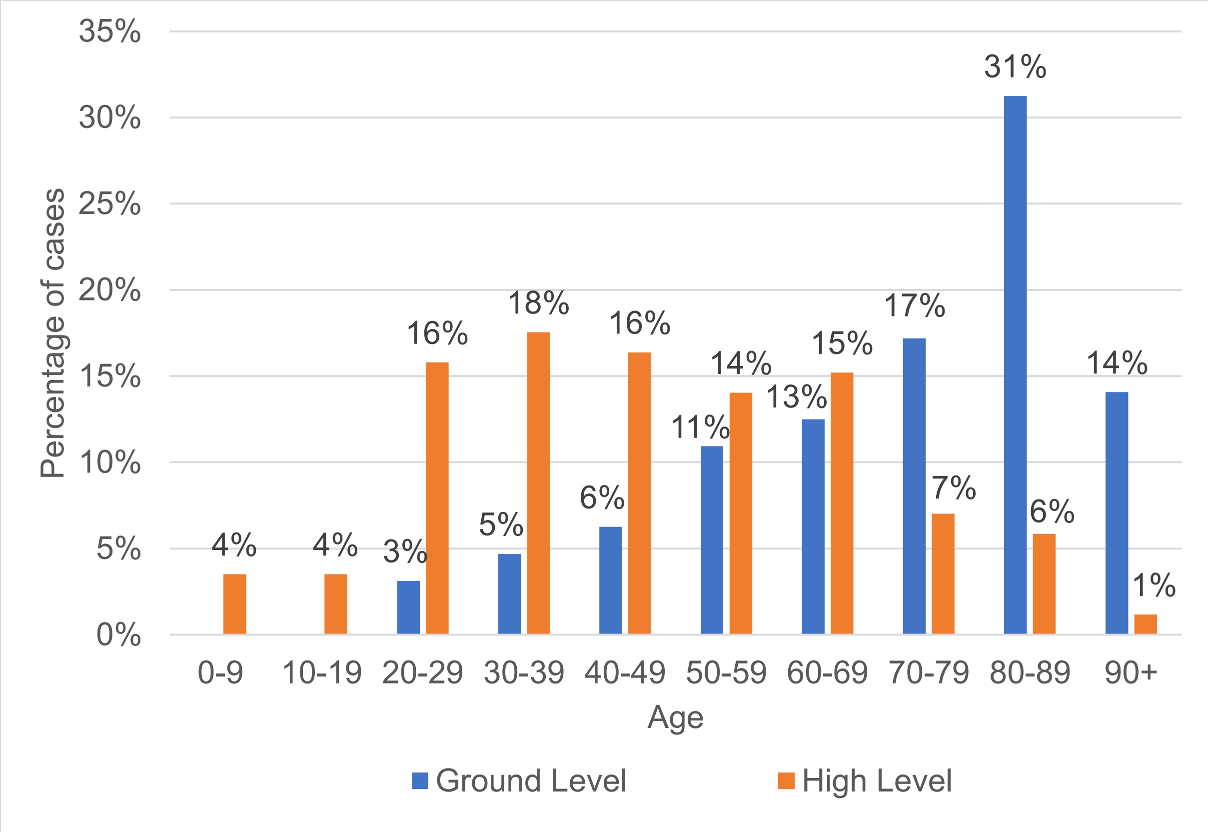

Figure 4. 2: Percentage age distribution of fall victims according to height from 2014 to 2018.

The data in figure 4.2 shows that there is an association between the age of the individual and the height from which the fall is initiated ($p<0.001$). Ground level falls start to increase with an increase in age (50-59 age group to 90+), a steady increase was observed from the 50-59 age group and peaked in the 80-89-year olds. Conversely, falls initiated from heights other than ground level were observed in all age groups but peaked in the 20-49-year age groups thereafter a decrease in the number of FFH cases was noted with an increase in age.

4.2.2 Sex

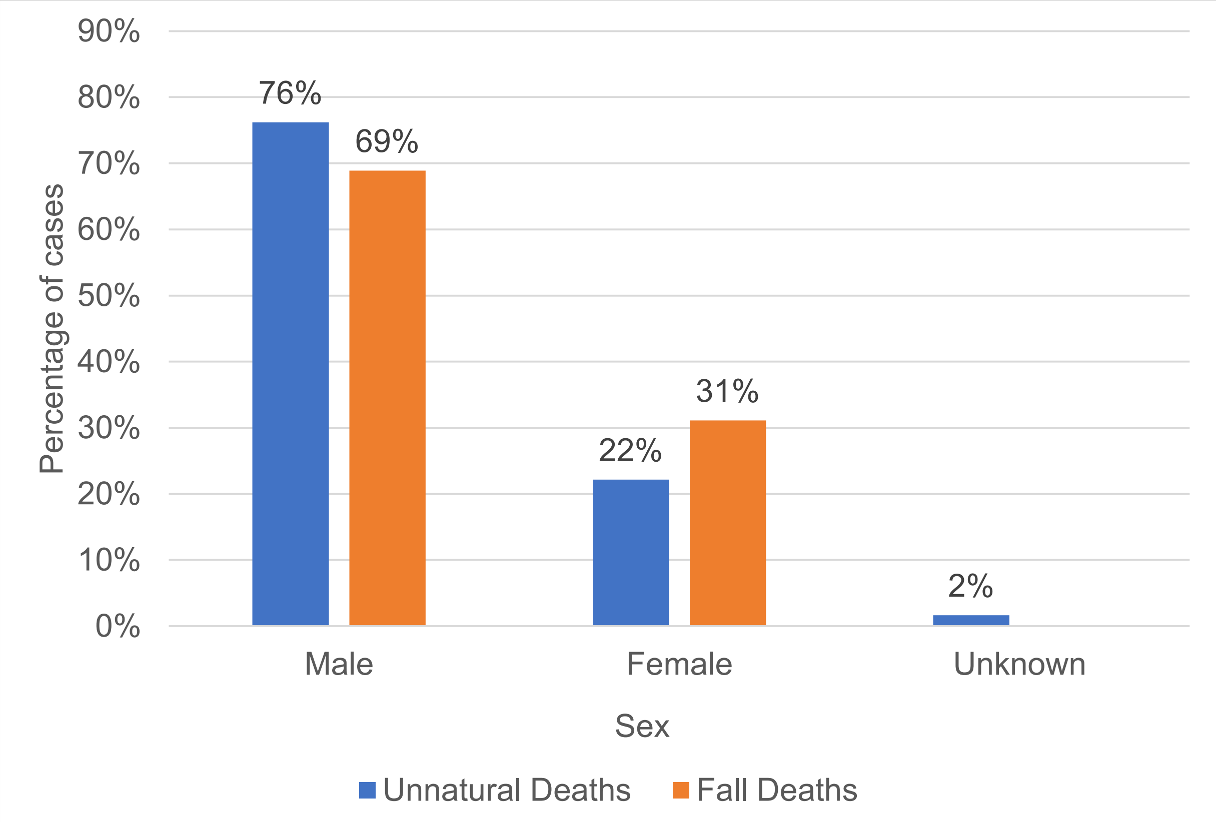

Figure 4. 3: Percentage sex distribution of all fatalities over the five-year period from 2014 to 2018.

Figure 4.3 shows that the total number of cases admitted at the SRM from 2014 to 2018 was composed of 76% (14 283), 22% (n=4 153), and 2% (n=308) cases of males, females, and unknown sexes respectively. Analysis of the data showed that 2% (n=248) of the total male cases and 3% (n=112) of all female cases were fall-related fatalities. A closer analysis of these deaths revealed that of the 360 fall deaths admitted into the SRM 69% (n= 248) accounted for males which were more than twice the total number of female (31%; n=112) cases.

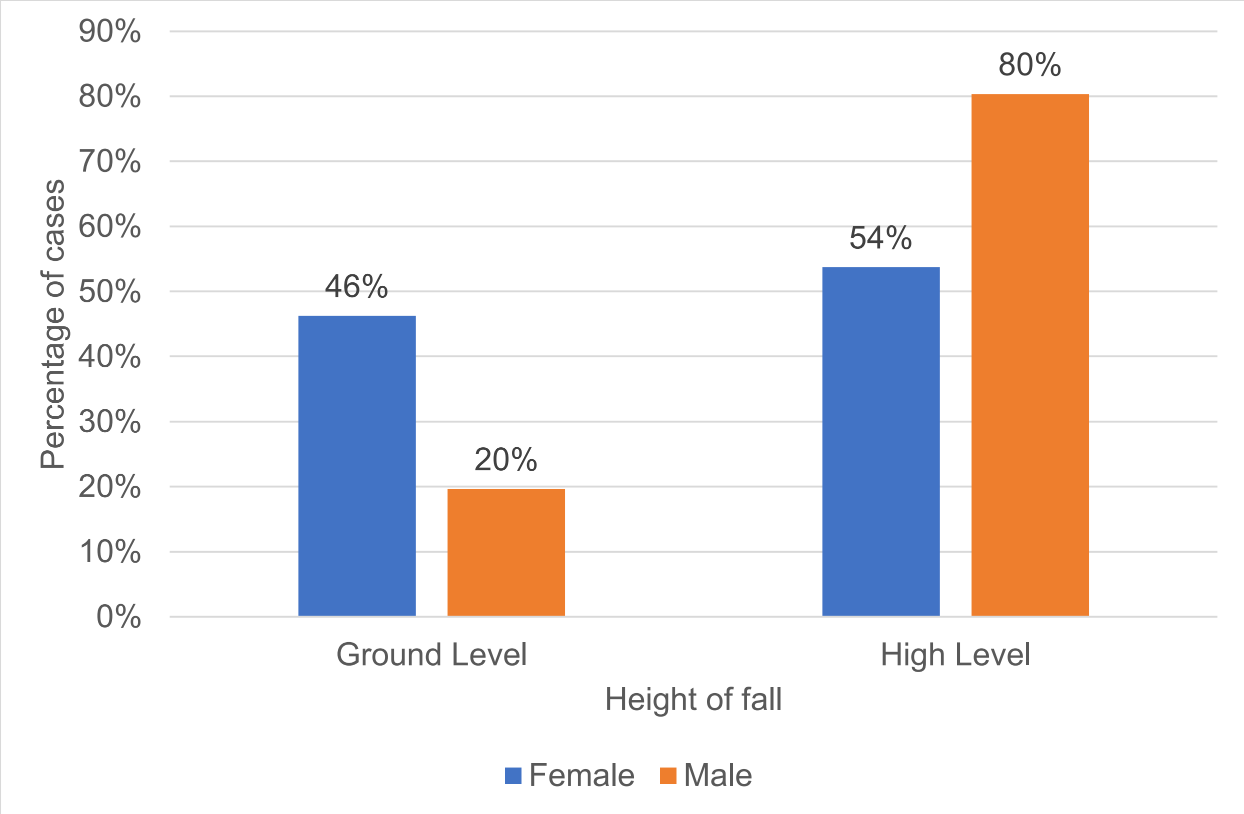

Figure 4. 4: Percentage sex distribution of fall victims according to height from 2014 to 2018.

There is an association between the sex of the individual and the height of fall ($p<0.001$). Of the 235 cases with recorded heights, information retrieved revealed that 46% (n=31) of females fell at ground levels compared to only 20% (n=33) of males.

4.3 Geographic location and site of fall

4.3.1 Geographic Location

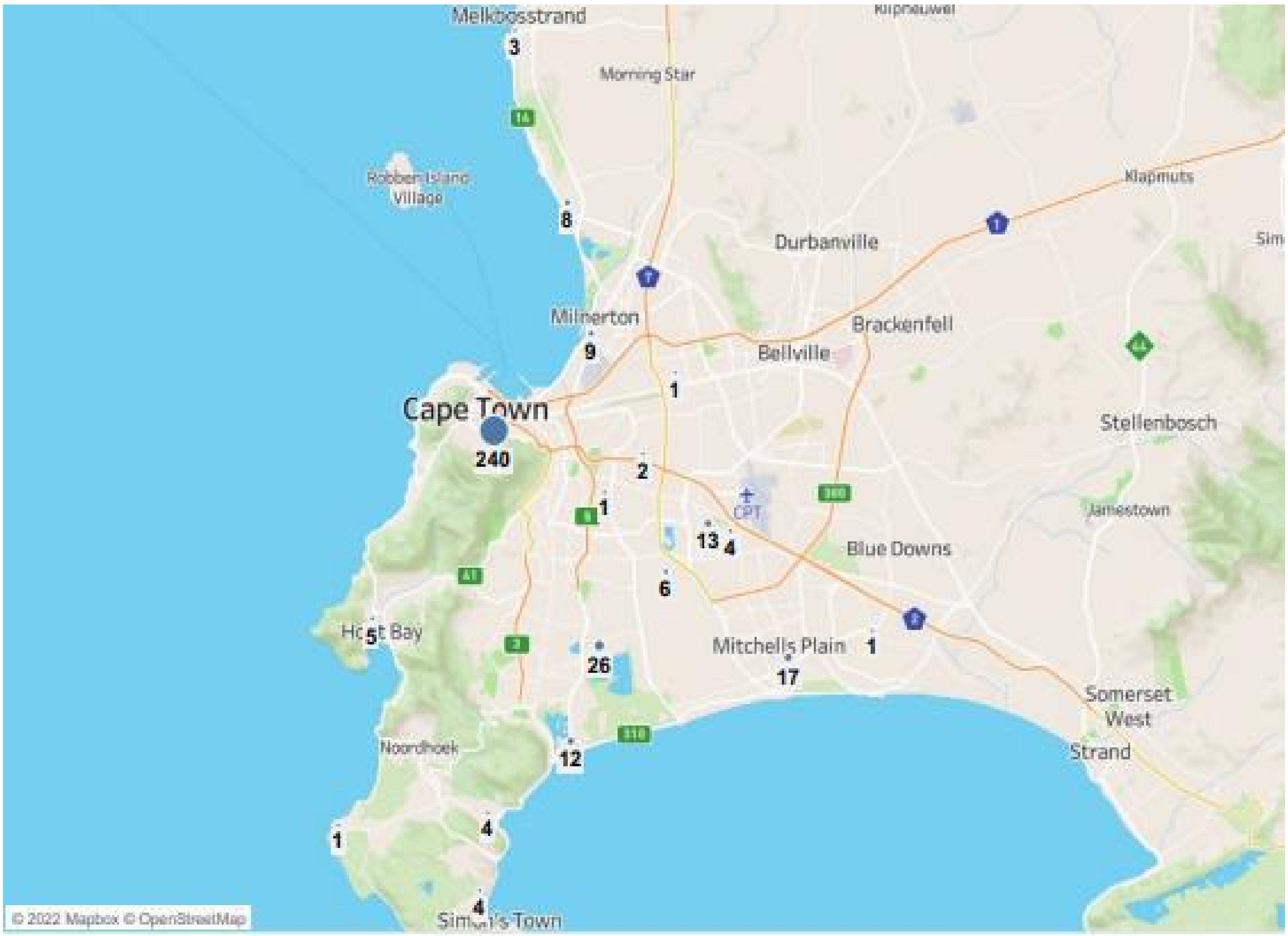

Figure 4. 5: Fall locations over the 5-year period from 2014 to 2018. Map obtained from Open Street View.

Records showed that cases included in this study occurred in 36 areas/suburbs. As seen in Figure 4.5, most of the fall scenes were located in Woodstock (n=102) and Cape Town Central (n=59) which also covers Wynberg (n=28), Diep River (n=25), Maitland (16), Claremont (n=12), and Lentegeur (n=11). The remaining locations in Figure 4.5 have a total number of cases ranging between (n=1) and (n=10).

Records showed that a majority of ground level falls were observed in Woodstock (n=14) and Wynberg (n=10). Cape Town Central and Diep River each recorded six cases while four cases were seen in both Maitland and Mitchells Plein. Falls from a height occurred in Woodstock (n=52) and Cape Town Central (n=33). Ground level cases were not as common as high level falls as they were absent in 14 areas (Camps and Hout Bay, Fish Hoek, Grassy Park, Khayelitsha, Kirsternhorf, Langa, Lansdowne, Manenberg, Mowbray, Muizenberg, Philippi, and Philippi East areas and Simon's town) compared to falls from a height which were not observed in Melkbosstrand.

4.3.2 Site of fall

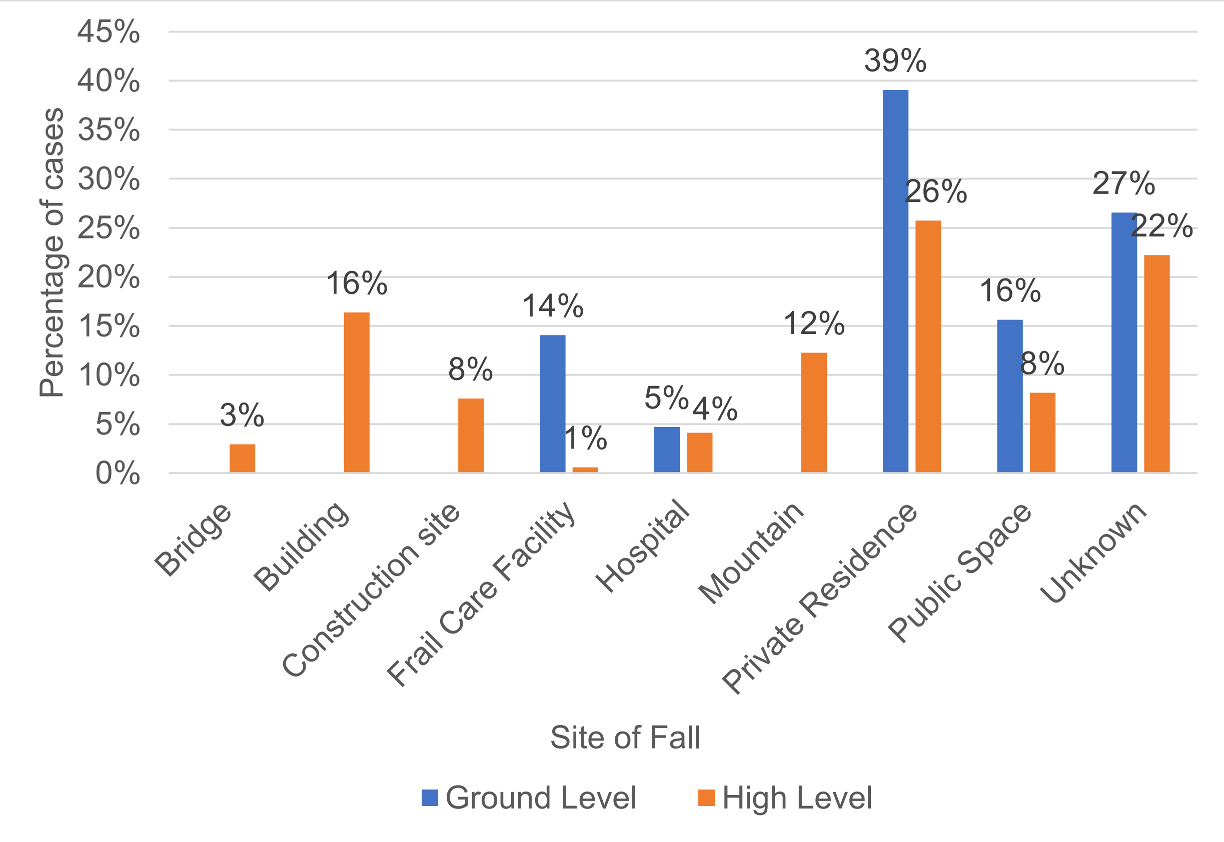

Figure 4. 6: Site of fall fatalities over the 5-year period from 2014 to 2018.

The site of the fall was recorded in 239 (66%) cases. Where the site of the fall was known, private residences (31%; n=111) were more common compared to other sites such as public spaces (9%; n=31) and building sites (8%; n=30). Mountain cases in the Western Metropole district were recorded in (7%; n=25) of the cases while frail care facilities and bridges were reported in (4%; n=15) and (1%; n=5) of the cases, respectively. Construction sites (n=13) and hospitals (n=11) had a similar distribution of 3%.

Ground level falls were observed in private residences (39%; n=25), public spaces (16%; n=10), frail care facilities (14%; n=9), hospitals (5%; n=3) and unknown sites

(27%; n=17). Falls from high levels were observed across all sites. A majority of these were seen in Private residences (39%; n=44), unknown sites (22%; n=38), building (16%; n=28), mountains (12%; n=21) public spaces (8%; n=13) and construction sites (8%; n=13). Heights were unknown in 121 (34%) cases, 54% (66) of these were from unknown sites, followed by frail care facilities (4%; n=5), mountains (3%; n=4), private residences (34%; n=42), public spaces (6%; n=7). There is a significant difference between the site where the fall occurred and the age of the deceased (p<0.001). As seen in the study, the majority of private residence deaths were observed in people aged between 50 – 90+ years. Individuals aged between 80-89 years typically experienced falls in frail care facility premises while mountain deaths were observed in individuals aged between 20 and 69 years. Construction deaths were common in the 30-39 age group while falls occurring in public spaces were common in all age groups.

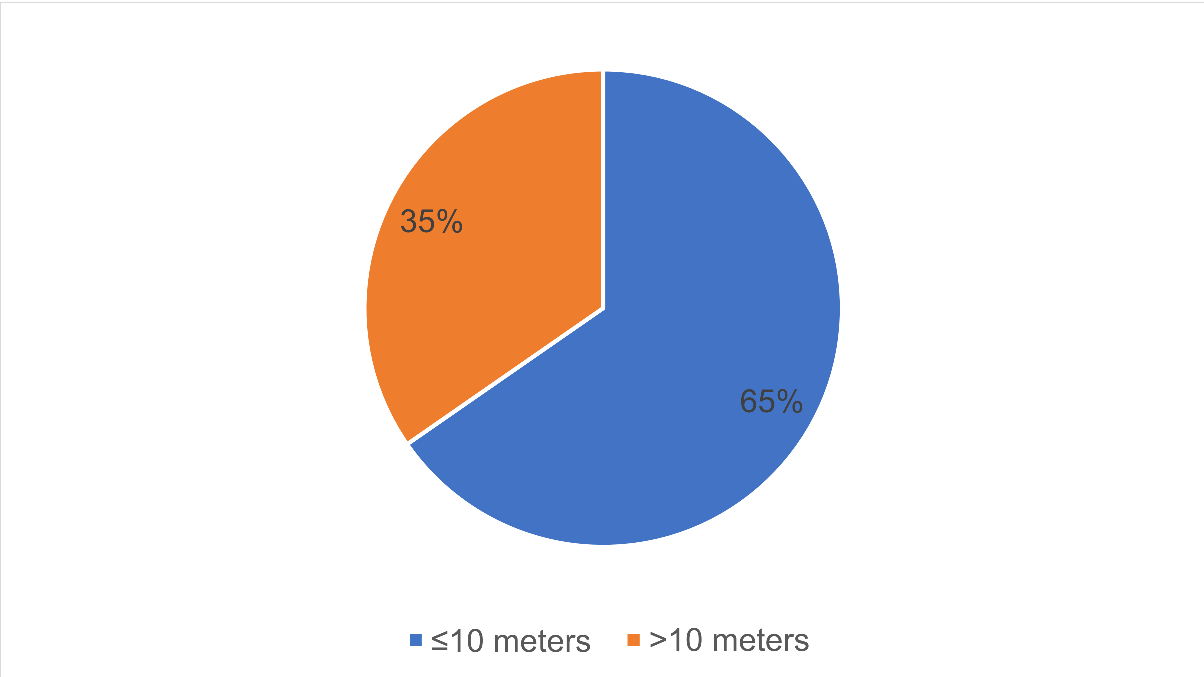

Figure 4. 7: Distribution of known height in cases of high level falls from 2014 to 2018.

Of the 171 high falls, specific heights were reported in 59% (n=101) of the cases as mentioned above. A closer look at these heights showed that half of the staircase deaths occurred at private residences while the remaining occurred in public and unknown spaces. The ≤ 10 meters category with 65% (n=66) of cases consisted of deaths that were initiated at heights less than or equal to ten meters (n=16), three stories (n=2) and two floors (n=2), four cases falling from beds i.e., two from the top bunk mattress and hospital beds. Fall cases accounted for by the >10meters category include cases above; ten-meter heights (n=8), second floor (n=24), three stories (n=2), and one death resulting from a paragliding accident where the pilot lost control of the paragliding equipment and subsequently impacted a residential roof before landing on the ground.

4.3.3 Landing Surface

230 cases (64%) in this study landed on non-deformable surfaces while unknown surfaces were recorded in 129 (36%) case files. One (<1%) case was noted to have allegedly landed in a body of water located next to a mountain where it is assumed the individual fell from.

4.4. Alleged Manner of Death

4.4.1 Distribution of alleged manner of death and height

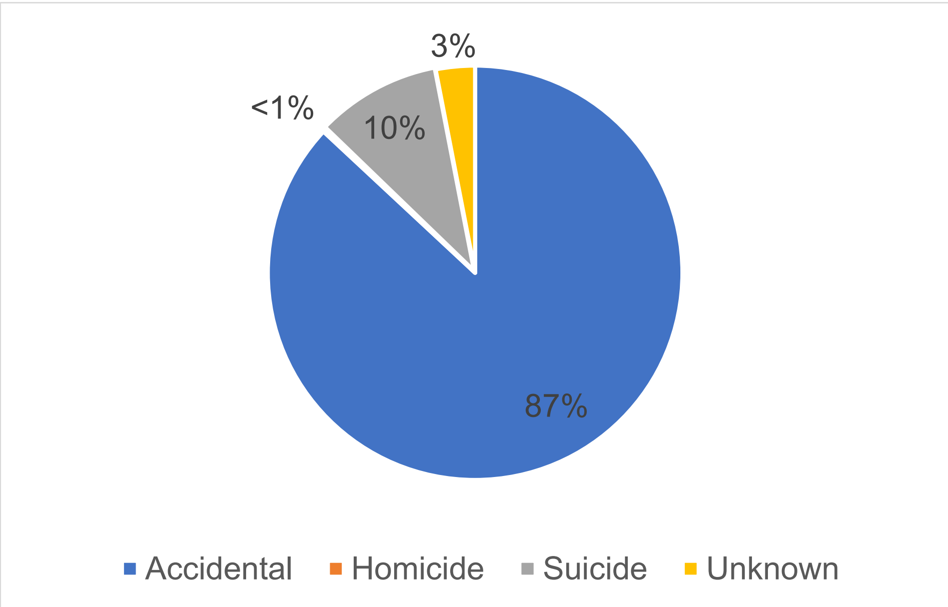

Figure 4. 8: Alleged manner of death distribution of fall fatalities over the five-year period from 2014 to 2018.

Figure 4.8 demonstrates the distribution of cases according to the alleged manner of death. The majority of the fatalities in this study were accidental (87%; n=313) in nature. One homicide case (<1%) was noted during this period while suicide fatalities constituted 10% (n=35) of the total cases in this study. The manner of death was unknown in 3% (n=11) of cases.

A total of 64 ground level fatalities occurred these were composed of 63 (98%) accidental and one (2%) unknown alleged manner case while a majority of high level falls were composed of 134 (78%) accidental, 35 (21%) suicidal, and one (<1%) case each recorded in the unknown and homicidal categories. The homicide case reported, involved a 36-year-old male who was allegedly pushed off a third-floor balcony. A total of 116 (93%) cases were observed at unknown heights while a total of nine cases were observed from unknown heights with unknown circumstances.

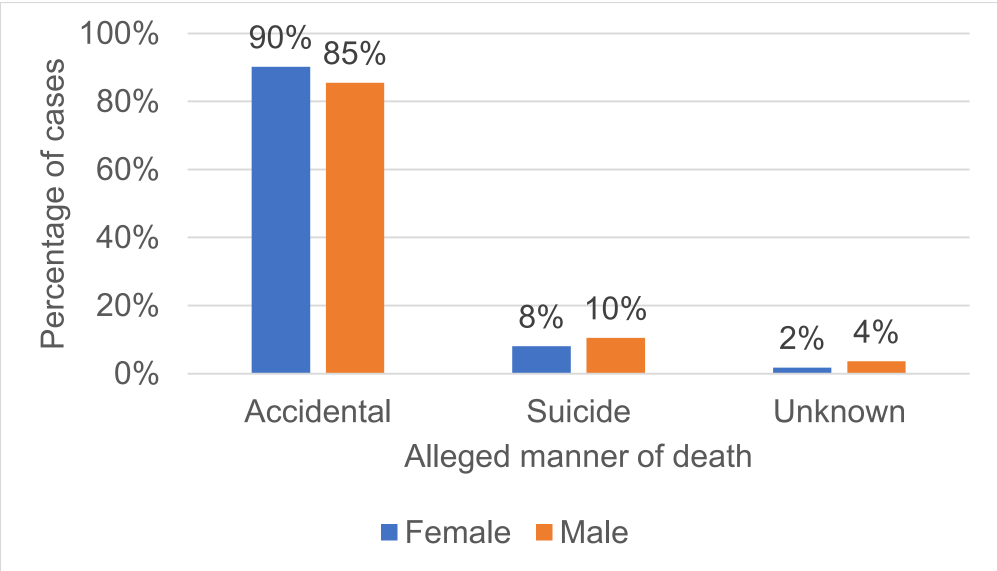

Figure 4. 9: Percentage sex distribution and manner of death in fall cases.

A comparison of the sexes and the circumstances surrounding the deaths of victims included in Figure 4.9 shows that a majority of both sexes died from accidental falls (females: 90%; n=101) (males: 85%; n=212). A greater proportion of males (10%; n= 26) committed suicide by jumping compared to females (8%; n=9). The single homicide case was found to be male. There is no statistically significant association between the alleged manner of death and sex (p=0.580).

4.5. Cause of Death

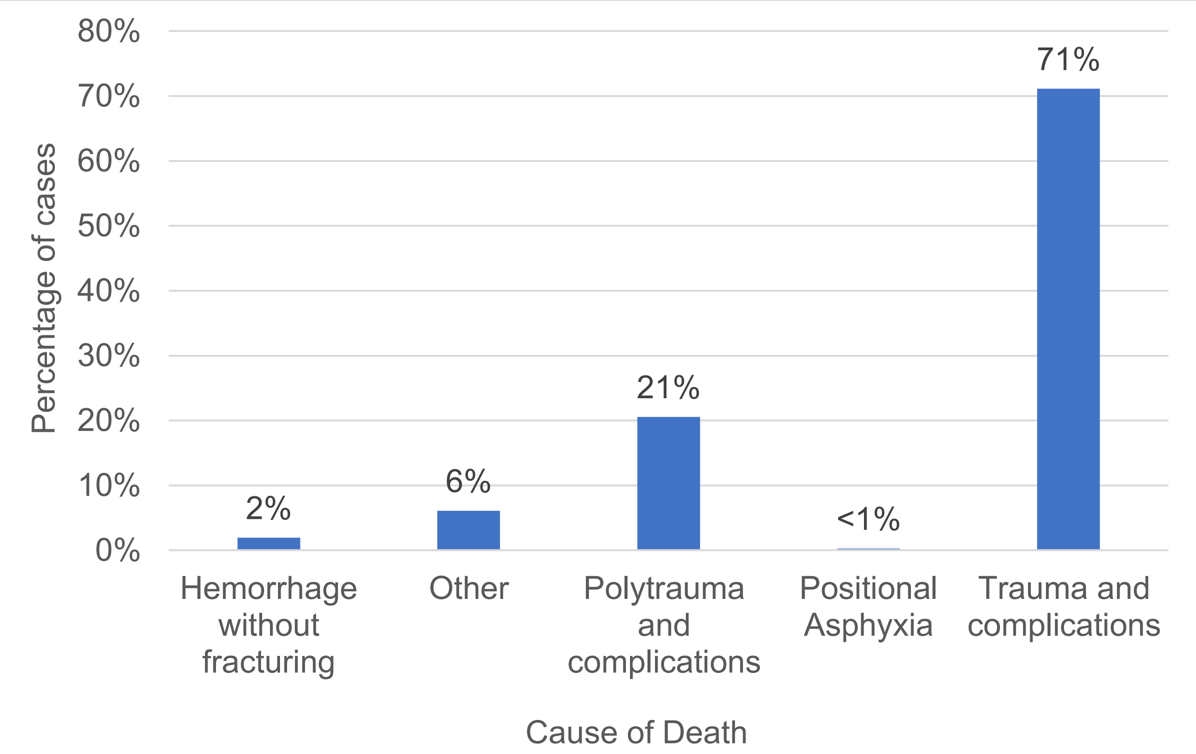

Figure 4. 10: Cause of death distribution in fall cases over a five-year period 2014-2018.

Cause of death is the initial event that set-in motion a chain of circumstances that culminated in death for example in this study, trauma is an injury to one region, and polytrauma describing injuries to two or more regions of the body are causes of death. Figure 4.10 shows that trauma to a single region and its associated complications was the leading cause of death consisting of 71% cases (n=256), a majority of these were head (n=150) and lower-limb (n=42) injuries followed by polytrauma and associated complications/consequences 21% (n=74) of the cases. Hemorrhage was the cause of death in 2% of the cases while 6% were recorded under "other" (cardio-related, hospital complications, and undetermined cause of death cases). One fall death was reported to have occurred in a car park where the deceased fell from a rooftop and landed on the ground. No injuries were sustained; however, they were found with a twisted neck which resulted in positional asphyxia and subsequent death. There is an association between the height from which a fall is initiated and the resulting cause of death ($p<0.001$).

Records showed that 51 of the ground level cases in this study were admitted into a medical center before death, where the average survival period was 9.6 days. There were four cases in which the individuals were found dead on the scene due to spinal and/or head injuries. Were falls from a height were concerned, 89 victims were taken to a medical center before succumbing to their injuries (mean survival period of 6.6 days), 67 died on the scene and three died on arrival at a medical center.

4.6. Blood Alcohol Results

Out of a total of 360 cases included in this study, blood for alcohol sampling was collected in 122 (33%) cases (12 GLF, 93 FFH, and 17 unknown height cases). At the time of this study, results were available for 116 of these cases (95%).

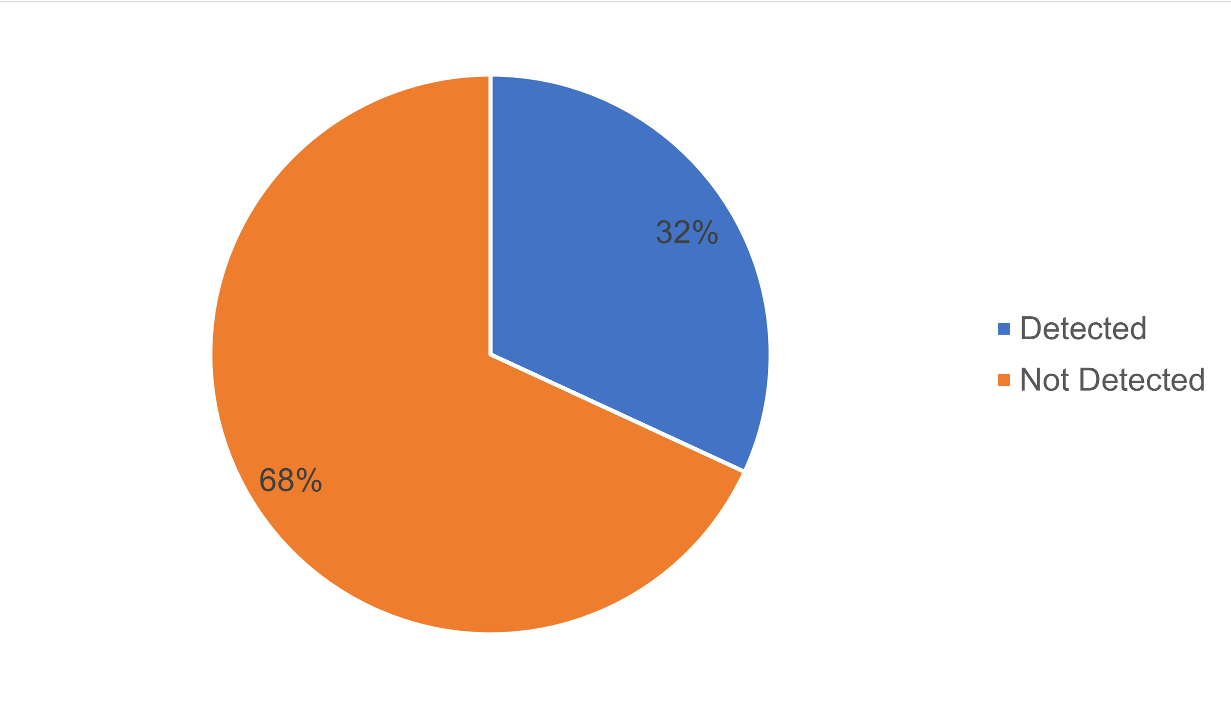

Figure 4. 11: Distribution of blood alcohol results in tested cases.

As seen in figure 4.11 alcohol was not detected in 68% (n=79) (8% (n=6) GLF and 75% (n=59) FFH) and detected in 32% (n=37) of the sampled cases (16% (n=6) of all GLF cases and 76% (n=28) of FFH).

Of the 37 cases in which alcohol was detected, 19% (n=7) had moderate (<0.05g/100ml) quantities of alcohol in their system while 81% (n=30) were found to have a BAC greater than 0.05g/100ml. There is no association between the amount of alcohol consumed and the alleged manner of death (p=0.728), number of injured regions (p=0.688), sex (p=0.878), and age (p=0.446) of individuals in this study.

4.7. Fall Injuries

4.7.1 Injuries in fall fatalities at different heights

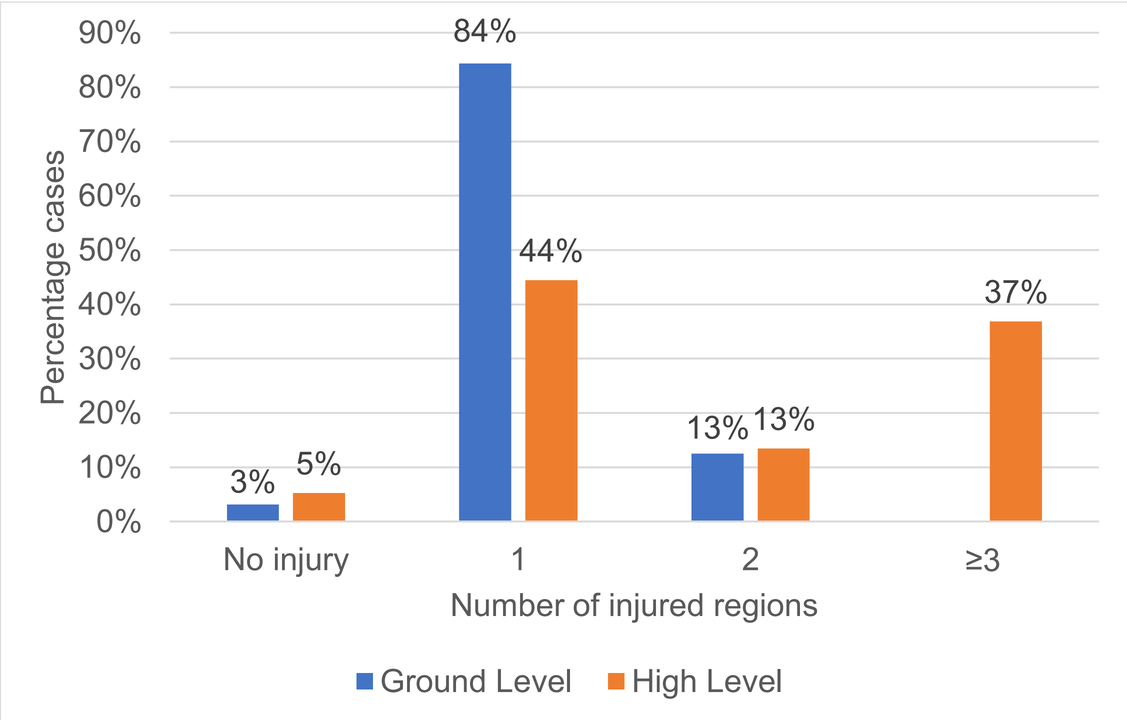

Figure 4. 12: Distribution of the number of injured anatomical regions from different fall heights over the five-year period from 2014 to 2018.

As illustrated in figure 4.12, injuries tend to cluster in at least one anatomical region across all heights in this study. Both heights (ground level (3%; n=2) and high level (5%; n=9)) had cases in which no injuries (either skeletal or soft tissue) were observed/recorded. The study shows that most ground level falls (84%; n=54) have only a single injured region with a maximum of two injured regions (13%; n=8) compared to high level falls which typically have more than three injured regions (37%; n=63) and a total of 76 cases (44%) with one injured region. The 125 cases with unknown fall heights were excluded from figure 4.12, however, similar to known heights, analysis of these case files showed that 2% (n=3), 86% (n=107), 8% (n=10) and 4% (n=5) cases had no injuries, injuries to 1, 2, 3 or more regions respectively.

4.7.2 Soft Tissue Injuries

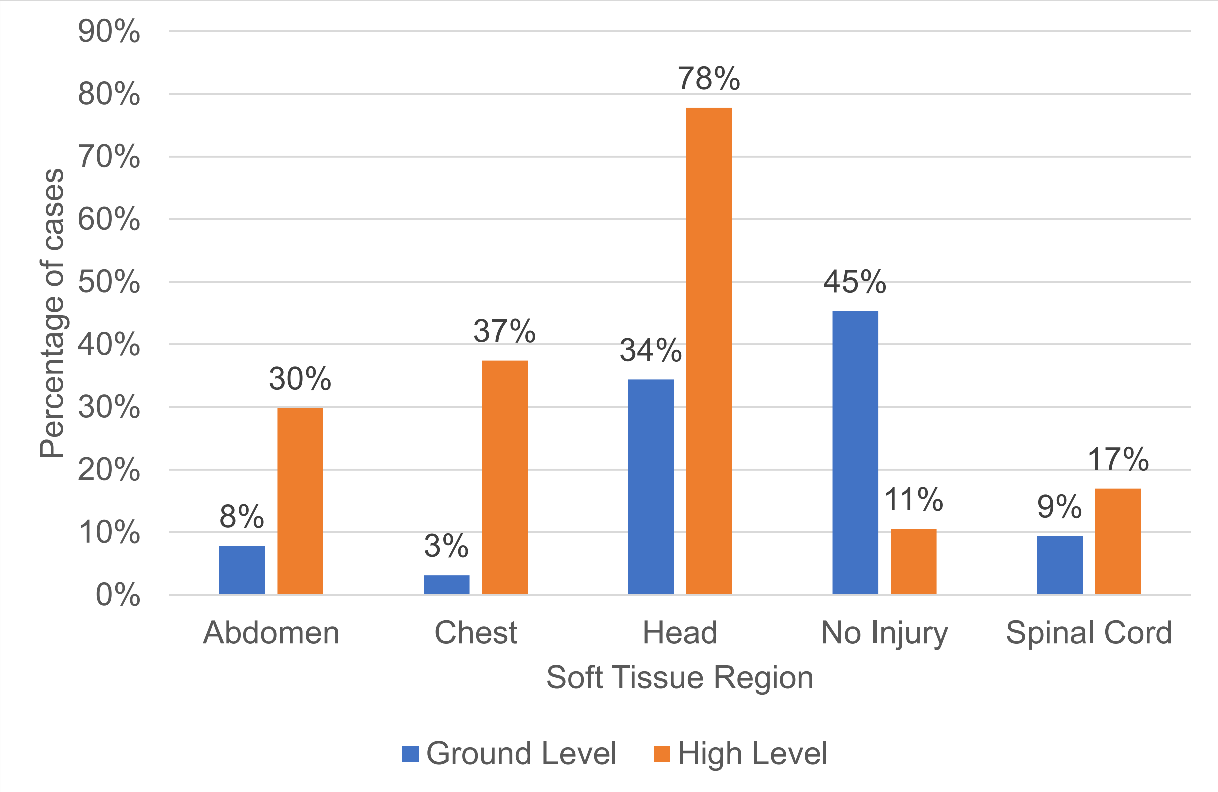

Figure 4. 13: Distribution of soft tissue injuries at different fall heights over the five-year period from 2014 to 2018.

There was a total of 771 soft tissue injuries in 180 cases. 12% (n=92) of these were found in ground level falls and the remaining 88% (n=682) were seen in high level falls.

Head injuries were the most predominant injuries in both high level (78%; n=133) and ground level falls (34%; n=22). Subdural hemorrhages were the leading head injury in-ground falls while subarachnoid hemorrhages (n=135) followed by contusions (n=104) and subdural hemorrhages (n=79) were frequent in high level falls.

At ground level, 9% of the observed cases showed trauma to the spinal cord, the cervical spine was mostly affected, two cases showed cervical transections. In high falls, 17% (n=29) of the cases showed spinal injuries with eight transections in the cervical region, three in the thoracic, and two in the lumbar regions.

In terms of chest injuries, two cases were observed at ground level both with hemorrhages in the intercoastal spaces (5^{th} to 8^{th} ribs areas), one of these involved a lacerated heart associated with rib fractures. Lacerations to the lungs and descending thoracic aorta were observed in high falls. Contusions and lacerations to the lungs were seen in 117 cases (68%) of high falls. There were 10 cases (6%) in which laceration of the descending thoracic aorta was observed and five cases (3%) in which the diaphragm showed contusions and lacerations.

The abdominal region was injured in only 8% (n=5) of the ground level falls affecting the retroperitoneal tissue in neck of femur fracture cases. This was not the same in falls from a height with 51 cases (30%) displaying injuries to this region. The liver was lacerated in 39 cases, the spleen in 16 cases, and the pancreas in four cases. 20 of these cases also showed injuries to the kidneys (n=10), bladder (n=7), and adrenal glands (n=3).

4.7.3 Skeletal injuries

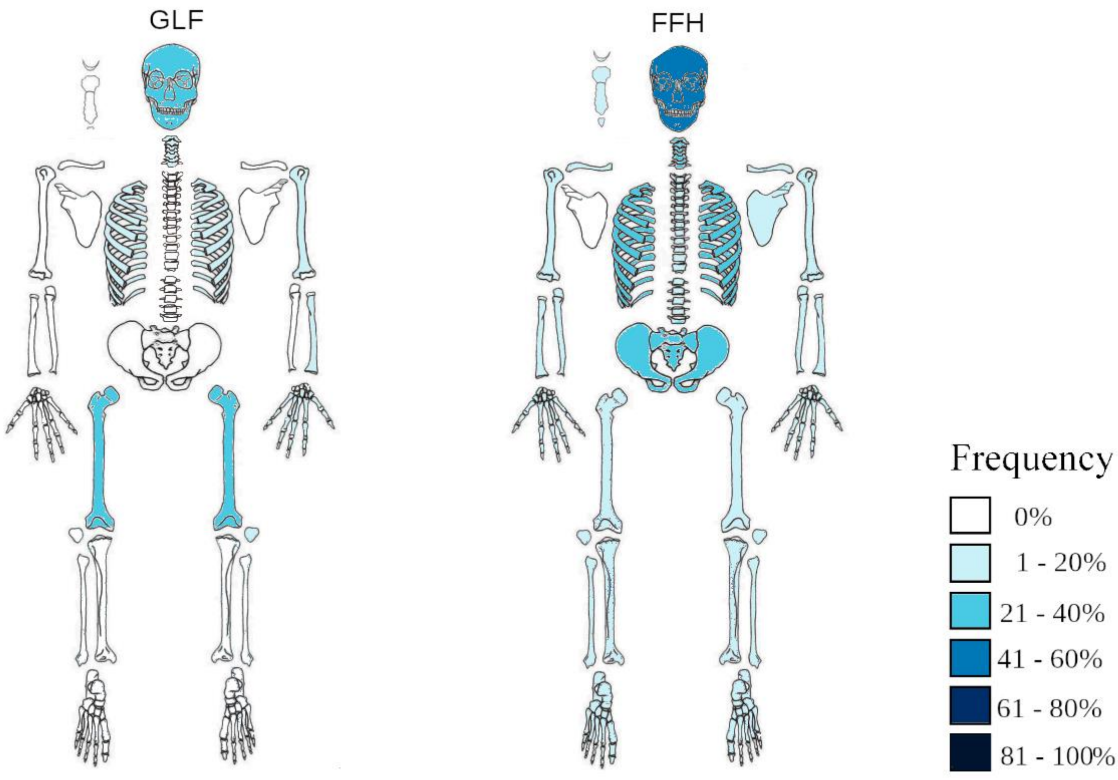

Figure 4. 14: Distribution and percentage frequency of skeletal injuries and dislocations resulting from ground level falls and falls from a height.

Results from the study as presented in figure 4.14 show that more skeletal regions are fractured and at greater frequencies in high level falls as compared to GLF falls. Statistically, it was observed that there is an association between sustained injuries and the height of the fall. Fractures were absent in 11 cases, five (8%) of these fell at ground level and six (4%) from a height. Significantly fewer injuries were seen in GLF compared to FFH ($p<0.001$).

Head

An analysis of ground level cases showed that 22% (n=14) of these cases sustained head trauma. The temporal bones accounted for 6% (n=4) of cases while the occipital and parietal bones both contributed 5% (n=3) of the total cases. The fracturing of facial (5%; n=3) and frontal (2%; n=1) bones also contributed to the total finding. There was an increase in the frequency and distribution of fractures to this region in high falls. A total of 90 (53%) cases with head injuries were observed in high level cases. The distribution of fractures to individual bones of the skull in high level falls was as follows: zygoma and nasal bones (11%; n=19), maxilla and mandible (9%; n=16), frontal (11%; n=18), occipital (16%; n=27), parietal (12%; n=21), temporal (30%; n=51) and cranial base-vault (35%; n=62). There is no significant difference between head injury proportions in the different fall heights ($p>0.05$).

Vertebral Column

Injuries to the vertebral column were sustained in both ground level falls and falls from a height with a predominance in high falls (37%; n=63). A breakdown of these showed that the cervical vertebrae (21%; n=36) accounted for a majority of the injuries followed by the thoracic (12%; n=20) and lumbar (4%; n=7) vertebrae while a total of five (8%) ground level cases had injuries to the cervical spine only. There is no statistically significant difference between vertebral column injury proportions in the different fall heights ($p>0.05$).

Hyoid bone fractures were observed in three (2%) cases. These cases were all associated with falls from a building. Two of these were suicidal and one accidental in which alcohol was detected.

Chest Injuries

Analysis of chest injuries indicated that this region is susceptible to fractures, however, height determines the frequency at which these occur. There were seven cases with chest injuries observed in ground level falls, none appeared to have bilateral injuries.

High level falls showed greater intensity with 93 (54%) cases displaying injury to the chest region (32 left,40 right, and 21 cases with bilateral injuries). Sternal fractures were seen in 15 (9%) high fall cases. No fractures were observed on the clavicles and scapulae in ground level falls whereas high falls presented 11 (6%) clavicle fractures and two (1%) scapula cases of scapula fracture. Both scapula fractures were on the left side, occurring in accidental falls from a mountain and 2-meter height respectively. Bilateral injuries to the clavicle were seen in four cases while five and two cases had injuries to the left and right sides, respectively. There is no significant difference between chest injury proportions in the different fall heights ($p>0.05$).

Upper limbs

Figure 4.14 shows that compared to high level falls, upper-limb fractures are not frequently seen in falls initiated at ground level. There are four GLF cases with injuries to the upper limb and one other region in this study. Two (3%) humeral fractures on the left side were noted involving females aged 89 and 104 years, both of whom sustained upper and lower limb fractures. The former sustained a fracture at the humeral neck and the latter fractured their humeral shaft proximally. Fracturing of the wrist bones was observed in one (2%) case. Similarly, only a single case displayed a fracture of the radius. No cases of ground level fall presented with a fracture of the ulna.

This was not the case in high falls as ulna injuries were observed in 10 (6%) cases, five (3%) on the left, three (2%) on the right side (two cases sustained bilateral fractures). In the case of the radius, 11 (6%) cases were observed, six (4%) on the left, seven (4%) on the right-hand side (two cases sustained fractures bilaterally). The wrist was fractured in two (1%) cases on the left and a dislocated wrist was observed in one (<1%) case on the right-hand side. Dislocations were also seen at the elbow joint in six (4%) cases (one bilateral case). Fractures to the humerus increased fivefold (6%; n=5) in high falls compared to the ground level falls. Cases from high levels showed no neck of the humerus injuries were recorded however the shaft was injured proximally and distally in two (1%) and three (2%) of the cases, respectively. Side distribution of the humerus showed there were five (3%) cases with left-hand and seven (4%) with right-hand side humeral fractures. There is no significant difference between upper-limb injury proportions in the different fall heights ($p>0.05$).

Pelvic injuries

Pelvic injuries were absent at ground level, while 36 (21%) cases were observed at greater altitudes. Injuries to this region were accounted for by eight (5%), five (3%), four (2%), 19 (11%) cases sustaining injuries to the sacroiliac joint, pubic rami, pubic symphysis, and unspecified areas of the pelvis. There is a significant difference between pelvic injury proportions in the different fall heights ($p<0.05$).

Lower limbs

Variations in the position of femur fracture injuries were observed. A total of 28 (44%) femur fractures (left=15 and right=14) were seen in ground level cases, all located on the neck of the femur and none of these were bilateral. High falls had 31 femur fractures, 10 to the left, 15 to the right, and six bilaterally. Two of the bilateral cases included in this study were seen to have femoral fractures located proximally in suicidal cases from buildings. Further analysis of these revealed that these fractures occurred at two distinct areas of the femoral bone; neck of femur (left=5 and right=3), femur shaft (left=14 and right=11), and unspecified positions (2 cases on both sides).

There were five cases with knee injuries resulting from high falls. Knee dislocations were observed in two of these cases; right (<1%), in addition to the dislocation, three other cases were observed on the left side (2%), one fractured and two with unspecified injuries. Three of these cases were accidental, seen in mountain fall deaths and the remaining two were suicidal from buildings. The dislocations were seen in a building suicide and mountain accident. At ground level, only one case (1.6%) with injury to the knee was seen which involved an 88-year-old female who died from post-operative complications associated with the injury.

Tibia and fibula fractures were absent in ground level falls. However, this was not the case at greater heights. Tibia fractures were noted in 19 cases (11%), seven from the left, eight from the right, and four bilaterally. In 11 of these cases, the individual fell from a building: nine suicides and two accidents; and eight occurred on mountains: seven accidents and one suicide. 18 fibula fractures were observed from high falls.

Seven on the left side, eight on the right, and three cases had bilateral fractures. Eight of these cases fell from buildings: Seven suicides (two from the hospital) and one accident and nine of the cases fell from mountains: eight accidental and one suicide. The remaining case was accidental, and the file did not show the fall site. One of the bilateral cases noted in the study sustained fractures to both bones maintaining fractures to the upper part of the bones on the left side. Similarly, another mountain case showed left side fractures located distally on both bones

The feet were affected in high level falls only. Analysis showed nine high fall cases, eight of these had ankle injuries and one case with bilateral injuries to the phalanges of both feet sustained from a mountain fall by an intoxicated individual. Five of the ankle cases resulted from high-rise buildings, three jumps, and one accidental fall from the 6^{th} floor causing bilateral injuries to the ankles. There is a significant difference between lower-limb injury proportions in the different fall heights ($p<0.05$).

5. Discussion

Falls are preventable yet they are the second leading cause of unintentional deaths in the world. The WHO ranks fall-related deaths second amongst accidental deaths (WHO 2022). The current study set out to review fall case records to investigate the demographic characteristics, prevalence and evaluate injuries sustained with an emphasis on the traits that can be utilized to discriminate between GLF and FFH.

5.1. Prevalence of fall-related deaths

Falls are avoidable, however, resulting injuries and subsequent deaths continue to increase. In this study, fall fatalities accounted for 1.92% of the total fatalities investigated at SRM in the 5-year period. Findings of the present study are not necessarily a reflection of other regions/mortuaries in South Africa and because there are few studies relating to fall fatalities from various heights in South Africa, comparing the present study to others proved difficult. In the current study, fall height was not recorded in 35% of the cases. This is not a new occurrence, Ramadan *et al*., (2020) found this to be the case in 7% of their cases. In Sweden, Freeman *et al*., (2014), reported that sufficient data relating to fall height and circumstances was available 60% of their study.

5.2. Demographic distribution of fall-related deaths

5.2.1 Age

Results from this study support the notion that fall-related deaths among the elderly are indeed a public health concern. Falling at ground level/same level/standing height is a common cause of injuries and death for the elderly (Martuchi *et al*., 2020) because of the increase in bone rigidity and loss of bone density that occurs with age making them more prone to injury and fracturing (Kieser 2012). In younger age groups with stronger more resistant bones, a significant amount of energy is required to cause injury which is associated with greater heights. We noted that death from these heights are common in the younger, economically active population who engage in occupational activities e.g. construction work (Dong *et al*., 2013). Furthermore, it has been established that the risk of fall death remains a problem for the elderly, in a one-year age group analysis study carried out in Brazil, 44% of the study population was in the 80+ age group, similar to the current findings (Martuchi *et al*., 2020).

5.2.2 Sex

The current study indicates that more males compared to females are admitted into SRM, further analysis revealed that a majority of females fall from standing/ground level height while more males fall from high levels. Compared to males, females are at a greater risk of dying from fall-related circumstances compared to other unnatural death causes. This is in accordance with Australian statistics which revealed that fall deaths were higher for females than males (Henley and Harrison 2009). Fall injuries are not the same among the different sexes especially when age is considered. As reported by Martuchi *et al*., (2020) a predominance of males was observed across all age groups but more females were noted in the older groups (80+ years). Falls are related to the aging process as the health state of an individual and bone density decreases with age. This leads to an increase in non-fatal and fatal fall-related injuries (WHO 2022). Yokota *et al*., (2020) researched the occurrence of injuries in the elderly at different heights and observed that more females (66.7%) fell at ground level while more males (66.9%) fell from a height.

5.3. Geographic location and site of fall

5.3.1 Geographic Location

Analysis of geographical locations revealed that a majority of falls occurred in the region of the Cape Town CBD (Table Mountain also falls within this region). It may be suggested that this is due to the multiple high-rise work and residential buildings as well as multiple construction sites in the area. Furthermore, the city is home to mountains e.g., Table Mountain, Devil's Peak, Chapman's Peak, Signal Hill, and Lions Head with multiple climbing and hiking trails used for recreational and sporting activities by residents and visitors. Falls from these mountains are common. A retrospective study on deaths on Table Mountain found 71% of FFH's deaths were as a result of inadequate signage and trail maintenance, victims venturing alone, failure to follow instructions, and taking up activities that were beyond their capabilities (Maistry, 2015).

5.3.2 Site of fall

Falls from both height categories revealed that a majority of the falls occurred in private residences similar to (Gulati *et al*., 2012). Schick and colleagues (2018), also observed that the majority of GLF occurred at home (Schick and colleagues 2018). Compared to falls from a height, ground level falls occurred in fewer sites i.e., private residences, public spaces followed by frail care centers in line with Hartshorne *et al*., (1997) who found that bedrooms, bathrooms, and living rooms are common slip, trip, stumble areas. Roads, gardens, churches, and hospitals are some examples of public spaces for falls. A majority of falls from frail care centers were initiated from sitting positions i.e., commodes, chairs, and beds.

Private residences, buildings, construction sites, mountains, and bridges were common sites for the occurrence of falls from a height. A majority of high falls at home occur from windows, balconies, trees especially during the summer when people are trying to cool off the heat, this could not be confirmed in the study as seasonal data was not collected (Gulati *et al*., 2012). It is further suggested that the reason why homes experience more falls compared to construction sites is because a greater emphasis is placed on worker safety in industrial settings compared to homes (Goren *et al*., 2003). Missteps when ascending and descending a flight of stairs are common as well as loss of balance due to inebriation (Schick *et al*., 2018). Other causes include the use of weak unbalanced ladders in low-income settings (Gulati *et al*., 2012), and working in fall hazardous environments with little or no knowledge of safety precautions (Dong *et al*., 2013).

Fewer cases in this study occurred at heights above 10meters, this is not unusual as Ramadan *et al*., (2016) found that a majority of their cases fell from heights less than 12 meters similar to Murthy *et al*., (2012).

5.3.3 Landing Surface

Regardless of the fall height (unknown heights excluded), non-deformable surfaces were predominant in this study with one case found in water, similar to the findings of Rowbotham *et al*., (2018a).

5.4. Alleged manner of death

5.4.1 Distribution of alleged manner of death

As seen in previous studies, all GLF cases in this study were accidental. FFH deaths were accidental, suicidal, and homicidal in descending order. These findings are consistent with Turgut *et al*., (2018) and Rowbotham *et al*., (2018a) but contrary to studies by Fanton *et al*., (2007) and Rowbotham *et al*., (2019a) studies where they found fewer accidental deaths compared to suicides. Generally, suicides by jumping are not as common as other methods of suicide (Wyatt *et al*., 2000; Piazzalunga *et al*., 2020). Pushing someone from a height is not a common method of homicide in South Africa which is similar to findings in an Australian study by Rowbotham *et al*., (2019a) where only one fall-related death was considered a homicide.

5.5. Cause of death

In the current study, trauma to one region followed by poly-trauma, both with associated complications were the most prevalent causes of death. This is contrary to the findings of Ramadan *et al*., (2020), who observed that more than 70% of their study consisted of poly-trauma deaths. In a study by Martuchi *et al*., (2020), complications following trauma involving infections were the leading cause of death, followed by traumatic brain injury.

5.6. Blood Alcohol Concentration

South Africa has a relatively high alcohol consumption rate which is associated with motor vehicle collisions, violence, and homicides (Seggie, 2012). Blood for alcohol sampling was collected in more FFH cases compared to GLF cases. Compared to the latter, there were more FFH cases with a BAC >0.01g/100ml, a majority of these were accidental falls. Alcohol has been frequently noted in accidental FFH in other regions (Fanton *et al*., 2007), however, this was not an observation in this study.

5.7. Fall Injuries

5.7.1 Injuries in fall fatalities at different heights

As previously noted, the extent of injuries seen in a fall is due to several intrinsic and extrinsic factors. All regions of the body are equally susceptible to soft tissue injuries and skeletal fractures. It is important to appreciate the physical properties surrounding a fall for these dictate the type and pattern of injuries on the body (Warner and Demling 1986). A predominance of injuries to one region was observed in GLF and injuries to three or more injuries were observed in high falls consistent with Petaros *et al*., 2013 who found that the number of injured regions decreased along with a decrease in height. It is rare to find a single injured region in a FFH case (ElGohary et al., 2016).

5.7.2 Soft Tissue injuries

Subdural injuries were frequently observed in GLF while subarachnoid hemorrhages were observed in FFH. The latter is in accordance with Turgut *et al*., (2018) whose fall from a height study reported subarachnoid hemorrhages as common in fall trauma cases. Chest injuries were prominent in FFH cases appearing as lacerations to the lungs and descending thoracic aorta. GLF soft tissue injuries observed in the abdominal region were associated with femoral fractures. Records for FFH cases showed injuries to the liver, spleen, and pancreas in descending order, most of these organs were lacerated. A plausible explanation for this lies with the amount of energy that is produced, depending on the fall height as well as the non-deformable impact surface.

5.7.3 Skeletal Injuries

Fracture localization declines with an increase in height (Petaros *et al*., 2013). Researchers have established that falls from a height commonly result in skeletal injury to the regions of the head, followed by the chest, abdomen, and extremities in descending order (Bruno *et al*., 2014). This is similar to the findings in the current study. GLF cases in this study do not follow this pattern, in descending order, the head, lower extremities, vertebra, and chest. Similar to Petaros *et al*., (2013), an absence of bilateral fractures was observed in heights below 4 meters, fractures were more generalized as height increased; FFH fractures in this study were scattered around the entire skeleton. Bilateral fractures in the current study were observed in FFH cases because of the large amounts of energy generated while falling from greater heights and non-deformable surfaces which do not allow for energy dissipation and because of the mechanics of ground level falls, it is unlikely that both sides of the body will impact the surface unless there is an attempt to break the fall using two arms. Fractures to the ribs, upper and lower extremities, were observed in this study similar to the findings of Rowbotham *et al*., (2019b) and Petaros *et al*., (2013). Thus, the presence of Bilateral fractures may indicate a fall from a height.

Head

The skull consists of twenty-two bones. Due to BFT, depending on the fall height, different patterns and frequencies may be observed on these bones. We discovered that skull fractures are not as frequent in ground level falls as they are in falls from a height. Furthermore, high falls tend to cause fracturing of more than one skull bone and often lead to comminution of the bones compared to the ground level falls which may result in a closed fracture or a fracture that is isolated in one bone.

In terms of the HBL rule, literature presents a variation of HBL definitions. This lack of standardization in terms of HBL demarcations and boundaries makes analysis difficult. Furthermore, similar to Preuss et al., (2004), the exact location of fractures (inferior/superior part of a bone) in this region was unspecified therefore a conclusion regarding the position of fracture and HBL rule could not be performed. The current study showed low skull fracture frequency with fewer fractures to the occipital bone which are expected in GLF's (Hein and Schulz 1989). One GLF case was observed with fractures to the frontal bone, this supports the findings of Petaros *et al*., (2013), that frontal bone fractures are common in heights above 10.5meters. These authors also noted a predominance of cranial base vault fractures consistent with this study in FFH. Their findings also showed that temporal and occipital bone fractures are common in lower falls, this could be true, however, height results in this study were not specific/sufficient enough for us to evaluate this.

Skull fractures are predominant in high falls because of three reasons; firstly, the skull requires a lot of energy which can only be generated from high falls, secondly, primary impact to the head (head-first landing) entails that a majority of the energy absorbed from the landing surface is transmitted to the skull, lastly, indirect transmission of energy to the head through the vertebrae, this occurs when other body regions encounter the landing surface first e.g., in feet-first, knee-first, buttocks-first positions. Gupta *et al*., (1982) revealed that head injuries are severe in lower heights while Atanasijevic *et al*., (2005) found that they were common in heights below 7 meters and above 30meters. Contrary to these findings, results in this study showed that there were 14 (22%) cases with head fractures sustained at ground level falls and 90 (53%) cases from high falls, this can be attributed to the decedent's body position at the time of impact however the low case numbers in this study ground level group can be attributed to the low deceleration forces that occur when falls originate from same levels. Rowbotham *et al*., (2019a) found that maxilla fractures were common among males compared to females as fifteen of their cases showed fractures to this bone. They attributed this finding to the male to female ratio of decedents in their study which was also the case with Bogusiak and Arkuszewski (2010), who after analyzing the characteristics and epidemiology of zygomaticomaxillary fractures in Poland discovered that more than 80% of their cases were males. Contrary to this, maxilla fractures in this study were observed in eight cases of which five of these were females.

Vertebral Column

Compared to the thoracic and lumbar vertebra, the cervical spine is more commonly fractured in fatal falls. At ground level, Schick *et al*., (2018) observed cervical spine injuries in 4% of their cases, which is comparable to the current study. FFH results in the current study demonstrated that cervical vertebra fractures were more common than fractures in other regions of the spine, opposing the findings of Ramadan *et al*., (2020) and Bruno *et al*., (2014) who noted more injuries to the thoracic vertebrae in FFH.

Chest

Similar to skull injuries, compared to falls from a height, fewer chest fractures were observed in ground level falls in accordance with Atanasijevic *et al*., (2005) who found that the number of cases without chest fractures decreases with an increase in height. As mentioned before, the chest is the widest part of the body making it prone to fracturing with any landing position (horizontal/vertical) regardless of whether the impact force is direct or indirect. Furthermore, bilateral rib fractures occur in falls from greater heights (Petaros *et al*., 2013). The energy formed during flight is also a factor; lower levels produce lower energy levels hence fewer fractures are produced; greater heights, generate sufficient energy to fracture more ribs (Rowbotham *et al*., 2018a).

High altitudes result in the fracturing of ribs in multiple areas, the sternum, and clavicles as seen in the current study. In their case study, Rowbotham *et al*., (2018b) noted that feet are the primary impact and due to secondary impacts, the pelvis, chest, and upper extremities may be fractured. Chest injuries resulting from this mechanism are indicative of a direct anterior-posterior impact on the chest wall common in horizontal deceleration/landing. One of the cases in the current study involved an individual who was found in a water body next to a mountain. Rib fractures were observed on the decedent in keeping with the findings of Lukas *et al*., (1981), Abel and Ramsey (2013).

Upper Extremities

In line with Mitchell and Aitken (2013) and Schick *et al*., (2018) fewer upper extremity fractures occurred in GLF's. Three cases with fractures to the humerus, radius, and wrist were observed in this study. A plausible explanation for this is side-first impacts which are often associated with an attempt to break the fall with their hands or arms as well as bone health and its susceptibility to fracturing.

Similar to Rowbotham *et al*., (2019a), two scapula fractures were identified in the present study. Compared to low-velocity ground falls, a longer fall distance is required to produce the necessary energy transferable to the scapula for fractures to occur. It is not known if they landed directly onto their backs or indirectly with a secondary posterior impact, what is known is that the scapular is protected anteriorly by the chest and posteriorly by surrounding muscles e.g., supraspinatus, trapezius, and latissimus dorsi. Furthermore, because of its movement capabilities, traumatic forces applied to it are dispersed rather than absorbed by the bone (Goss 2007). Scapula fractures are common in staircase FFH cases (Mitchell and Aitken 2013).

Pelvic region

Contrary to Schick *et al*., (2018), no pelvic bone fractures were observed in GLF's in the current study. At high levels, significant fractures were observed on the pubic ramus and sacroiliac joint. Contrary to Petaros *et al*., (2013), unilateral pelvic fractures were less frequent compared to bilateral fractures. Skeletal injuries to this region are not uncommon when the landing surface is non-deformable, and this was the landing surface for most of the cases in this study. The position of the pelvis allows for impact from two directions, vertically through axial compression and horizontally if the individuals fall anteriorly. The sacrum lies between the axial and appendicular skeletons, this makes it susceptible to shearing forces.

Lower extremities

Vertical deceleration causing lower-limb fractures is mainly associated with great heights and feet-first landing. There are fewer femoral fractures present in the young compared to the elderly (Martuchi *et al*., 2020). A majority of lower extremity fractures were observed in ground level falls however these were less frequent compared to head fractures (Yokota *et al*., 2020) as seen in the present study. Femur fractures noted in ground level falls occurred at the neck of the femur, this is a common phenomenon in the elderly population and is reflective of the present study population age group. In falls from a height, all lower extremity bones are susceptible to injury depending on the height of the fall. We did not observe feet injuries in ground level cases in this study. This is expected as researchers (Teh *et al*., 2003; Papadakis *et al*., 2016 and Katz *et al*., 1988) concur injuries to this area occur in falls from a height, specifically suicidal falls which often result in feet-first landings. However, this is not aligned with the findings from this study as only 7% of suicidal cases presented with feet injuries contrary to the findings of Ramadan *et al*., (2020) who observed feet injuries in 75% of their studies.

5.8. Limitations

In this investigation, only the details of the fall incident documented in the case files could be accounted for because of the nature of a retrospective study. Documentation of specific/precise fall heights, landing surfaces, and the fall site were not accounted for in some of the cases in the study. The nature of the study prohibited the ability to accurately determine the height of the fall. Furthermore, case files did not contain information on the shoes, carpeting, floor padding, lighting conditions, or barriers that may have contributed to the fall.

Due to the paucity in specific height details for FFH cases, all non-GLF falls were grouped into a broad FFH group even though different heights generate different speeds and energy before the resulting injury pattern hence some information was lost during interpretation. Variables influencing injury patterns such as landing position, BMI, and air drag were not accounted for. This should be considered when interpreting the data derived in this study.

As seen above, falls from heights in particular mountain falls included in the study did not include the mechanism of fall involved i.e., free fall or rolling downhill as this would help to determine if injuries were due to primary impact (free-fall) or secondary impacts (rolling downhill).

6. Conclusion/Recommendations

There is a paucity of fall studies in a medicolegal context in South Africa. Therefore, this study aimed to investigate the demographics, prevalence, and injury patterns observed in cases admitted to the SRM from 1 January 2014 to 31 December 2018.

Fall-related deaths were seen in 2% of unnatural deaths admitted at SRM during the 5 years of study. Most of the falls in this study occurred in private residences. Old age individuals are at a greater risk of falling at ground level and dying from fall-related causes while fatal falls in the younger population are more likely to occur from a height. More males compared to females were observed in the study, however, it can be deduced that females are at a greater risk of dying from falls while males die from other mechanisms.

Fall heights and landing surfaces are not always documented at the scene; in those that were documented, FFH cases were more prevalent than GLF cases. Where landing surfaces were recorded, non-deformable surfaces were prominent.

Most of the falls in the study occurred accidentally. Trauma and consequences were the most predominant cause of death. Soft tissue injuries were prominent in the head region in both heights while the abdomen appeared to be more common in FFH.

Skeletally, we observed an increase in the frequency of fractures with an increase in height. There was a preponderance of head and femur fractures in GLF. Bilateral fractures and fractures to the head, chest, pelvis and cervical spine were noted in FFH.

Findings from this study will aid in the identification and interpretation of injuries resulting from falls in the medico-legal community as well as add to the current work on the topic. Furthermore, findings can be used to either support or refute past and future studies. This study also shows that, falls are a cause of death in South Africa that should be studied further. We recommend that future studies apply more complex statistical methods to look at the variables holistically.

7. References

Abel, S.M. and Ramsey, S., 2013. Patterns of skeletal trauma in suicidal bridge jumpers: a retrospective study from the southeastern United States. *Forensic Science International*, *231*(1-3), pp.399-e1.

Ali, S., Destaw, Z., Misganaw, A., Worku, A., Negash, L., Bekele, A., Zergaw, A., Walker, A., Odell, C., Naghavi, M. and Abate, E., 2020. The burden of injuries in Ethiopia from 1990-2017: evidence from the global burden of disease study. *Injury Epidemiology*, *7*(1), pp.1-11.

Atanasijevic, T.C., Savic, S.N., Nikolic, S.D. and Djokic, V.M., 2005. Frequency and severity of injuries in correlation with the height of fall. *Journal of Forensic Science*, *50*(3), pp.1-5.

Atanasijevic, T.C., Popovic, V.M. and Nikolic, S.D., 2009. Characteristics of chest injury in falls from heights. Legal Medicine, 11, pp.S315-S317.

Bhattacharya, B., Maung, A., Schuster, K. and Davis, K.A., 2016. The older they are the harder they fall: injury patterns and outcomes by age after ground level falls. *Injury*, *47*(9), pp.1955-1959.

Bogusiak, K. and Arkuszewski, P., 2010. Characteristics and epidemiology of zygomaticomaxillary complex fractures. *Journal of Craniofacial Surgery*, *21*(4), pp.1018-1023.

Bruno, C.M., Alessio, B., Alberto, B. and Cristina, C., 2014. The injury pattern in fatal suicidal falls from a height: An examination of 307 cases. *Forensic Science International*, *244*, pp.57-62.

Chisholm, K.M. and Harruff, R.C., 2010. Elderly deaths due to ground-level falls. *The American Journal of Forensic Medicine and Pathology*, *31*(4), pp.350-354.

Christensen, A.M., 2004. The influence of behavior on freefall injury patterns: possible implications for forensic anthropological investigations. *Journal of Forensic Sciences*, *49*(1), pp.5-10.

Clark, C., Mole, C.G. and Heyns, M., 2017. Patterns of blunt force homicide in the West Metropole of the City of Cape Town, South Africa. *South African Journal of Science*, *113*(5-6), pp.1-6.

Deprey, S.M., Biedrzycki, L. and Klenz, K., 2017. Identifying characteristics and outcomes that are associated with fall-related fatalities: multi-year retrospective summary of fall deaths in older adults from 2005–2012. *Injury Epidemiology*, *4*(1), pp.1-10.

Dong, X.S., Choi, S.D., Borchardt, J.G., Wang, X. and Largay, J.A., 2013. Fatal falls from roofs among US construction workers. *Journal of Safety Research*, 44, pp.17-24.

Dragu, M., Salem, A. and Marinescu, M., 2009. Forensic assessment of blunt thoracic trauma-correlations between pattern of injuries and trauma dynamics. *Romanian Journal of Legal Medicine*, *17*(2), pp.122-126.

ElGohary, M.S., Elmadah, E.I. and Wahdan, A.A., 2016. Falling from height: an interesting unusual pattern of injuries. *The Egyptian Journal of Forensic Sciences and Applied Toxicology*, *16*(1), pp.23-35.

Fanton, L., Bévalot, F., Schoendorff, P., Lalliard, S., Jdeed, K. and Malicier, D., 2007. Toxicologic aspects of deaths due to falls from height. *The American Journal of Forensic Medicine and Pathology*, *28*(3), pp.262-266.

Formiga, F., Navarro, M., Duaso, E., Chivite, D., Ruiz, D., Perez-Castejon, J.M., Lopez-Soto, A. and Pujol, R., 2008. Factors associated with hip fracture-related falls among patients with a history of recurrent falling. *Bone*, *43*(5), pp.941-944.

Fracasso, T., Schmidt, S. and Schmeling, A., 2011. Commentary on: Kremer C, Racette S, Dionne CA, Sauvageau A. Discrimination of falls and blows in blunt head trauma: systematic study of the hat brim rule in relation to skull fractures. J Forensic Sci 2008 May; 53 (3): 716-9. *Journal of Forensic Sciences*, *56*(6), pp.1662-author.

Freeman, M.D., Eriksson, A. and Leith, W., 2014. Head and neck injury patterns in fatal falls: epidemiologic and biomechanical considerations. *Journal of Forensic and Legal Medicine*, *21*, pp.64-70.

Galet, C., Zhou, Y., Ten Eyck, P. and Romanowski, K.S., 2018. Fall injuries, associated deaths, and 30-day readmission for subsequent falls are increasing in the elderly US population: a query of the WHO mortality database and National Readmission Database from 2010 to 2014. *Clinical Epidemiology*, *10*, p.1627.

Goren, S., Subasi, M., Týrasci, Y. and Gurkan, F., 2003. Fatal falls from heights in and around Diyarbakir, Turkey. *Forensic Science International*, *137*(1), pp.37-40.

Goss, T.P., 2007. Fractures of the scapula: diagnosis and treatment. *Disorders of the Shoulder: Diagnosis & Management*, pp.793-840.

Granhed, H., Altgarde, E., Akyurek, L.M. and David, P., 2017. Injuries sustained by falls-a review. *Trauma Acute Care*, *2*(2), p.38.

Gupta, S.M., Chandra, J. and Dogra, T.D., 1982. Blunt force lesions related to the heights of a fall. *The American Journal of Forensic Medicine and Pathology*, *3*(1), pp.35-43.

Gulati, D., Aggarwal, A.N., Kumar, S. and Agarwal, A., 2012. Skeletal injuries following unintentional fall from height. *Ulus Travma Acil Cerrahi Derg*, *18*(2), pp.141-6.

Hartshorne, N.J., Harruff, R.C. and Alvord Jr, E.C., 1997. Fatal head injuries in ground-level falls. *The American Journal of Forensic Medicine and Pathology*, *18*(3), pp.258-264.

Hein, P.M. and Schulz, E., 1989. Accidental fall-induced craniocerebral injury. *Beitrage zur gerichtlichen Medizin*, *47*, pp.447-450.

Henley, G, and Harrison, J. 2009. Injury deaths, Australia 2004—05. Injury Research and Statistics Series. Canberra: Australian Institute of Health and Welfare.

Honkanen, R. and Smith, G., 1991. Impact of acute alcohol intoxication on patterns of non-fatal trauma: cause-specific analysis of head injury effect. *Injury*, *22*(3), pp.225-229.

Inquest Act, No 58 of 1959. 1959: Government Printer: Pretoria

Jamebozorgi, A.A., Kavoosi, A., Shafiee, Z., Kahlaee, A.H. and Raei, M., 2013. Investigation of the prevalent fall-related risk factors of fractures in elderly referred to Tehran hospitals. *Medical journal of the Islamic Republic of Iran*, *27*(1), p.23.

Johnston, J.J.E. and McGovern, S.J., 2004. Alcohol related falls: an interesting pattern of injuries. *Emergency Medicine Journal*, *21*(2), pp.185-188.

Katz, K., Gonen, N., Goldberg, I., Mizrahi, J., Radwan, M. and Yosipovitch, Z., 1988. Injuries in attempted suicide by jumping from a height. *Injury*, *19*(6), pp.371-374.

Kieser, J., 2012. Biomechanics of bone and bony trauma. *Forensic Biomechanics*, pp.35-69.

Kremer, C. and Sauvageau, A., 2009. Discrimination of falls and blows in blunt head trauma: assessment of predictability through combined criteria. *Journal of Forensic Sciences*, *54*(4), pp.923-926.

Kremer, C., Racette, S., Dionne, C.A. and Sauvageau, A., 2008. Discrimination of falls and blows in blunt head trauma: systematic study of the hat brim line rule in relation to skull fractures. *Journal of Forensic Sciences*, *53*(3), pp.716-719.

Lapostolle, F., Gere, C., Borron, S.W., Pétrovic, T., Dallemagne, F., Beruben, A., Lapandry, C. and Adnet, F., 2005. Prognostic factors in victims of falls from height. Critical care medicine, 33(6), pp.1239-1242.

Lefèvre, T., Alvarez, J.C. and de la Grandmaison, G.L., 2015. Discriminating factors in fatal blunt trauma from low level falls and homicide. *Forensic Science, Medicine, and Pathology*, *11*(2), pp.152-161.

Lu, F.P., Chan, D.C., Kuo, H.K. and Wu, S.C., 2013. Sex differences in the impact of diabetes on the risk of geriatric conditions. *Geriatrics & Gerontology International*, *13*(1), pp.116-122.

Lukas, G.M., Hutton Jr, J.E., Lim, R.C. and Mathewson Jr, C., 1981. Injuries sustained from high velocity impact with water: an experience from the Golden Gate Bridge. *The Journal of Trauma*, *21*(8), pp.612-618.

Maistry, S., 2015. *Retrospective analysis of deaths in the Table Mountain National Park 2000-2011* (Master's thesis, University of Cape Town).

Martuchi, S.D., de Andrade Batista, D.V., Karakhanian, A.C.M., Gianvecchio, D.M., Carvalho, D.D. and de Souza Nogueira, L., 2020. Postmortem analysis of fall victims according to age groups: a comparative study. *Journal of Trauma Nursing| JTN*, *27*(2), pp.111-120.

Mitchell, S.E. and Aitken, S.A., 2013. The epidemiology of fractures caused by falls down stairs. *International Scholarly Research Notices*, *2013*.

Murthy, C.V., Harish, S. and Chandra, Y.G., 2012. The study of pattern of injuries in fatal cases of fall from height. *Al Ameen J Med Sci*, *5*(1), pp.45-52.

National Health Act, No 61 of 2003. 2003: Government Printer: Pretoria

Norman, R., Matzopoulos, R., Groenewald, P. and Bradshaw, D., 2007. The high burden of injuries in South Africa. *Bulletin of the World Health Organization*, 85, pp.695-702.

Ooi, C.K., Goh, H.K., Tay, S.Y. and Phua, D.H., 2010. Patients with pelvic fracture: what factors are associated with mortality?. *International Journal of Emergency Medicine*, *3*(4), pp.299-304.

Osifo, O.D., Iribhogbe, P. and Idiodi-Thomas, H., 2010. Falls from heights: Epidemiology and pattern of injury at the accident and emergency centre of the University of Benin Teaching Hospital. *Injury, 41*(5), pp.544-547.

Papadakis, S.A., Pallis, D., Galanakos, S., Kateros, K., Leon, G., Machairas, G. and Sapkas, G., 2016. Suicide Attemps from height and injury patterns: an analysis of 64 cases. *Neurological and Mental Disorders*, *2*(1), pp.1-15.

Petaros, A., Slaus, M., Coklo, M., Sosa, I., Cengija, M. and Bosnar, A., 2013. Retrospective analysis of free-fall fractures with regard to height and cause of fall. *Forensic Science International*, *226*(1-3), pp.290-295.

Piazzalunga, D., Rubertà, F., Fugazzola, P., Allievi, N., Ceresoli, M., Magnone, S., Pisano, M., Coccolini, F., Tomasoni, M., Montori, G. and Ansaloni, L., 2020. Suicidal fall from heights trauma: difficult management and poor results. *European Journal of Trauma & Emergency Surgery*, *46*(2).

Preuss, J., Padosch, S.A., Dettmeyer, R., Driever, F., Lignitz, E. and Madea, B., 2004. Injuries in fatal cases of falls downstairs. *Forensic Science International*, *141*(2-3), pp.121-126.

Ramadan, M., Abdel Rahman, A., Mahmoud, N. and Allam, A., 2016. Pitfalls encountered during Documentation of Cases of Fatal Fall from Height Presented to Kafr EL Sheikh-Medico legal Department during the Period from (1999 to 2013). *Ain Shams Journal of Forensic Medicine and Clinical Toxicology*, *27*(2), pp.105-116.

Ramadan, A., Soliman, E., Abo El-Noor, M. and Shahin, M., 2020. Patterns of injuries in fatal fall from height cases in Gharbia Governorate: autopsy study. *The Egyptian Journal of Forensic Sciences and Applied Toxicology*, *20*(4), pp.27-42.

Rowbotham, S.K. and Blau, S., 2016. Skeletal fractures resulting from fatal falls: A review of the literature. *Forensic Science International*, *266*, pp.582-e1.

Rowbotham, S.K., Blau, S., Hislop-Jambrich, J. and Francis, V., 2018a. Skeletal trauma resulting from fatal low (≤ 3 m) free falls: an analysis of fracture patterns and morphologies. *Journal of Forensic Sciences*, *63*(4), pp.1010-1020.

Rowbotham, S.K., Blau, S. and Hislop-Jambrich, J., 2018b. The skeletal trauma resulting from a fatal BASE jump: A case study showing the impact of landing feet-first under extreme vertical deceleration. *Forensic Science International*, *286*, pp.e20-e27.

Rowbotham, S.K., Blau, S., Hislop-Jambrich, J. and Francis, V., 2019a. An Anthropological Examination of the Types of Skeletal Fractures Resulting from Fatal High (> 3 m) Free Falls. *Journal of Forensic Sciences*, *64*(2), pp.375-384.

Rowbotham, S.K., Blau, S., Hislop-Jambrich, J. and Francis, V., 2019b. An assessment of the skeletal fracture patterns resulting from fatal high (> 3 m) free falls. *Journal of Forensic Sciences*, *64*(1), pp.58-68.

Saukko, P. and Knight, B., 2015. Knight's forensic pathology. CRC press.

Schick, S., Heinrich, D., Graw, M., Aranda, R., Ferrari, U. and Peldschus, S., 2018. Fatal falls in the elderly and the presence of proximal femur fractures. *International Journal of Legal Medicine*, *132*(6), pp.1699-1712.

Seggie, J., 2012. Alcohol and South Africa's youth. *South African Medical Journal*, *102*(7), p.587.

Statistics South Africa. 2012. *Census 2011 Municipal report Western Cape*. Pretoria: Government Printer.

Statistics South Africa, 2015. Mortality and causes of death in South Africa: Findings from death notification: 2015. Statistical release P0309.3.

Tan, S. and Porter, K., 2006. Free fall trauma. *Trauma*, *8*(3), pp.157-167.

Teh, J., Firth, M., Sharma, A., Wilson, A., Reznek, R. and Chan, O., 2003. Jumpers and fallers: a comparison of the distribution of skeletal injury. *Clinical Radiology*, *58*(6), pp.482-486.

Thierauf, A., Preuß, J., Lignitz, E. and Madea, B., 2010. Retrospective analysis of fatal falls. *Forensic Science International*, *198*(1-3), pp.92-96.

Turgut, K., Sarihan, M.E., Colak, C., Güven, T., Gür, A. and Gürbüz, S., 2018. Falls from height: A retrospective analysis. *World Journal of Emergency Medicine*, *9*(1), p.46.

Türk, E.E. and Tsokos, M., 2004. Pathologic features of fatal falls from height. *The American Journal of Forensic Medicine and Pathology*, *25*(3), pp.194-199.

Warner, K.G. and Demling, R.H., 1986. The pathophysiology of free-fall injury [Abstract]. *Annals of Emergency Medicine*, *15*(9), pp.1088-1093.

World Health Organization. Injuries, Violence Prevention Department, World Health Organization, World Health Organization. Department of Injuries and Violence Prevention, 2002. *The injury chart book: a graphical overview of the global burden of injuries*. World Health Organization.

World Health Organization. 2022. *World Health Organization: Falls.* Available: https://www.who.int/news-room/fact- sheets/detail/falls [2022, January 2].

Wyatt, J.P., Beale, J.P., Graham, C.A., Beard, D. and Busuttil, A., 2000. Suicidal high falls. *Journal of Clinical Forensic Medicine*, *7*(1), pp.1-5.

Yokota, M., Fujita, T., Nakahara, S. and Sakamoto, T., 2020. Clarifying differences in injury patterns between ground-level falls and falls from heights among the elderly in Japan. *Public health*, *181*, pp.114-118.

Yoshida-Intern, S., 2007. A global report on falls prevention epidemiology of falls. *Geneva: WHO.*

8. Appendix

HREC Ethics Approval Letter

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

Room G50- Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: hrec-enquiries@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

18 March 2021

HREC REF: 153/2021

Mr C Mole
Forensic Medicine & Toxicology
Falmouth Building -FHS
Email: calvin.mole@uct.ac.za
Student: chnlor001@myuct.ac.za

Dear Mr Mole

PROJECT TITLE: A RETROSPECTIVE ANALYSIS OF FATAL GROUND LEVEL FALLS AND FALLS FROM A HEIGHT: A 5-YEAR REVIEW-MPHIL CANDIDATE-MISS RUMBIDZAI CHONYERA

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

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

This approval is subject to strict adherence to the HREC recommendations regarding research involving human participants during COVID -19, dated 17 March 2020 & 06 July 2020.

Approval is granted for one year until the 30 March 2022.

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

The HREC acknowledge that the student: Ms Rumbidzai Chonyera will also be involved in this study.

Please quote the HREC REF 153/2021 in all your correspondence.

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

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
NHREC-registration number: REC-210208-007

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use: Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines. The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.