



A comparative autopsy study of the injury distribution and severity between suicidal and accidental high falls

Maria Tsellou¹ · Artemis Dona¹ · Anastasia Antoniou² · Nikolaos Goutas¹ · Efstathios Skliros³ · Iordanis N. Papadopoulos⁴ · Chara Spiliopoulou¹ · Stavroula A. Papadodima¹

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Abstract

Falls are the second cause of accidental deaths worldwide. Falls from height are also a common method of suicide. The aim of this study is to compare the characteristics of the victims, the circumstances of the fall and the severity and distribution of the injuries reported in an autopsy case series of falls from height. This study is a retrospective analysis of consecutive autopsy cases of suicidal and accidental falls from height which were investigated in the Department of Forensic Medicine and Toxicology of the National and Kapodistrian University of Athens during the period 2011–2019. The recorded variables included demographic data of the victim, height of fall, length of hospital stay, toxicological results, the existence and location of injuries and Injury Severity Score (ISS). Victims of suicidal falls were younger (55.53 vs. 62.98, $p=0.001$), they fell from higher heights (12.35 vs. 5.18 m, $p<0.001$), and they sustained more severe injuries compared with victims of accidental falls (ISS 51.01 vs. 40.88, $p<0.001$). Injuries in the thorax, abdomen, pelvis, upper and lower extremities were more frequently observed after a suicidal fall (93.6% vs. 67.3%, 72.1% vs. 21.4%, 72.1% vs. 27.6%, 42.9% vs. 15.3%, 45.7% vs. 13.3%, respectively- $p<0.001$), probably due to the higher height of fall. Our study outlines the differences in the profile of the victims and in the severity of injuries caused by falls from height depending on the intention of the victim to fall. However, a distinctive injury pattern in victims of suicidal falls was not demonstrated.

Keywords Accidental fall · Suicidal fall · Fall from height · Autopsy · Injuries · ISS · Greece

Introduction

Falls from height have substantial fatal rates due to the multiplicity and the severity of the injuries sustained by their victims [1, 2]. According to the WHO, falls from height or ground level, are the second cause of accidental deaths worldwide, counting approximately 646,000 deaths annually [3]. Falls from height are also a common method of suicide,

used mostly in urban areas. Particularly in Asia, where there are several cities with high-rise buildings, the choice of this suicide method is remarkably common. In cities such as Singapore or Hong Kong, falls are the most frequent method of suicide, as the majority of residents live in high-rise buildings [4, 5]. In Europe, jumping from height seems to be used as a suicide method mostly in small, predominantly urban societies such as Luxembourg and Malta [6]. According to the latest data from the Hellenic Statistical Authority on the causes of death in Greece as they have been analyzed by the Suicide Observatory of the Center for Suicide Prevention of the non-governmental organization (NGO) “Klimaka”, falls are the second most common method of suicide after hanging [7].

There is an array of papers which attempt to investigate the factors that affect mortality after a fall from height [1, 8–12]. Parameters such as age, intention, alcohol consumption, height of fall, type of landing surface, type and

✉ Stavroula A. Papadodima
stpapd@gmail.com; stpapd@med.uoa.gr

¹ Department of Forensic Medicine and Toxicology, National and Kapodistrian University of Athens, Athens, Greece

² 2nd Department of Psychiatry, Attikon General Hospital, National and Kapodistrian University of Athens, Athens, Greece

³ Nemea Medical Center, Nemea, Corinthia, Greece

⁴ Henry Dunant Hospital Center, Athens, Greece

location of injuries have been highlighted by several studies as factors which affect the prognosis of a free fall [8, 9, 11].

In the literature, there has also been research studies concerning the comparison of the body injury distribution between people who sustained accidental and suicidal falls from height. Several studies have reported differences in the traumatic pattern between the above groups [13–17], while there is only one study in which no statistically significant difference was verified [18]. The aim of the present study is to compare the characteristics of the victims, the circumstances of the fall and the severity and distribution of the injuries reported in an autopsy case series of accidental and suicidal falls from height in an attempt to identify the role of intention in the outcome of the fall.

Materials and methods

All the cases of our Department are referred by the Investigative Authorities, as they involve sudden/unexpected or violent deaths and are submitted to complete autopsy (internal and external examination). The jurisdiction area of our Department includes approximately 1,000,000 people, who account for about 1/10 of the total Greek population [19].

A retrospective analysis of consecutive autopsy cases submitted to the Department of Forensic Medicine and Toxicology of the National and Kapodistrian University of Athens during the period from January 1, 2011 to December 31, 2019, was performed. The inclusion criteria were death due to fall from height and age of the victim above 18 years-old. Exclusion criteria were falls due to criminal acts, ground level falls, falls from any vehicle type (crane, elevator, etc.), cases subjected to secondary traumas (for example a traffic accident after fall from the bridge, etc.) and decomposition of the body.

Data collection was conducted retrospectively by a separate forensic pathologist, while the forensic pathologists responsible for the autopsies were not aware of the aim of the study at the time of performing them.

The cases retrieved were divided into suicidal (Group I) and accidental falls (Group II). Death scene findings, eyewitness accounts, security camera footage, the existence of a suicide note, previous suicide attempts and threats, history of mental illness were co-estimated in order to assess a suicidal intention of the victim. The probability of a homicidal fall among our sample cases was excluded by using information from the investigating authorities as well as by assessing circumstantial evidence and forensic findings.

In a few cases (for example in cases of falls from a bridge) an estimation of the fall height was available. However, in cases of falls from a building, the only available information for height was the number of floors. In these cases, the height of fall was estimated on the assumption that the height of one floor is 3 m (the average floor height) according to international standards and previous literature [20].

The recorded variables included demographic data of the victim (age, sex, psychiatric history), height of fall, length of hospital stay (in days), toxicological results, the existence and location of injuries. The injuries were presented according to their location into eight major body regions: head, thorax, abdomen, pelvis, upper limbs, lower limbs, cervical spine and thoracolumbar spine. Injury Severity Score (ISS) which is the sum of the squares of the maximum AIS (Abbreviated Injury Scores) in each of the three most severely injured body regions (out of six prescribed body regions - head and neck, face, thorax, abdomen, pelvic girdle and extremities, external) was calculated in order to assess the overall severity of injury in each selected case.

Alcohol analysis was performed in whole blood samples using a headspace gas chromatography flame ionization detector (HSGCFID) method. Psychoactive substances were detected in blood and urine samples using a screening immunochemical method (VIVAE, Siemens). Their presence in the blood was confirmed by validated in house gas chromatography/mass spectrometry (GC/MS) methods.

The study was approved by the Ethics Committee of the National and Kapodistrian University of Athens (1,415,018,370/8-6-2015) and data were collected and processed anonymously.

Statistical analysis of the collected data was performed using the statistical software SPSS Statistics 25.0 and significant were values with $p < 0.05$. Clinicodemographic characteristics were studied with mean values and \pm SD for continuous variables and with percentages for categorical variables. Normality of continuous variables was checked both statistically with the Kolmogorov-Smirnov test and diagrammatically through histograms. Comparisons were conducted by using Student's *t*-test and Pearson's Chi-square test for continuous and categorical variables respectively. Correlations were explored through the correlation coefficient Pearson's *R*. Finally, multiple linear regressions were performed, in order to decide the predictors of ISS.

Results

A total number of 261 cases were retrieved, out of 9986 autopsies performed during the time period 2011–2019. The manner of death was suicide in 140 cases (53.6%) and accident in 98 cases (37.5%). In the rest of cases, the manner of death was unknown. Clinicodemographic data are presented

Table 1 Sociodemographic and clinical characteristics (N=261)

Variables	Subgroups	Mean \pm SD or N (%)
Sex	Females	68 (26.1%)
Age		58.46 \pm 17.45
Psychiatric history	No	110 (42.1%)
	Substance use disorder	7 (2.7%)
	Major depressive disorder	63 (24.1%)
	Psychosis	25 (9.6%)
	Bipolar disorder	9 (3.4%)
	Anxiety disorders	10 (3.8%)
	Other/Unknown	37 (14.2%)
Height (meters)		9.35 \pm 7.34
Suicides		140 (53.6%)
Alcohol levels		0.16 \pm 0.60
Length of hospital stay (days)		4.06 \pm 14.02
Head injuries		191 (73.2%)
Chest injuries		218 (83.5%)
Abdominal injuries		134 (51.3%)
Pelvic injuries		143 (54.8%)
Upper limb injuries		81 (31%)
Lower limb injuries		89 (34.1%)
Cervical spine injuries		48 (18.4%)
Thoracolumbar spine injuries		110 (42.1%)
ISS		46.8 \pm 19.9

in Table 1. No statistically significant difference was noticed between genders concerning age and ISS. As far as suicidality is concerned, 73.3% of women and 53.9% of men committed suicide. Fisher's exact test showed that the difference was statistically significant ($p=0.010$). Student's t-test showed that victims of suicidal falls were younger, were hospitalized for a shorter period of time, fell from a higher height, and scored higher in the ISS (Table 2). Moreover, in deaths caused by suicide, chest, abdominal, pelvic, upper, and lower limb injuries were more often observed (Table 3).

Table 2 Comparison between suicidal falls and accidental falls using Student's T-test (N=238)

	Suicidal falls (Group I) n=140		Accidental falls (Group II) n=98		t	p
	Mean	SD	Mean	SD		
Age	55.53	18.016	62.96	15.06	3.345	0.001
Height (meters)	12.35	8.14	5.18	3.63	-7.722	<0.001
Length of hospital stay (days)	1.53	10.67	7.03	16.01	3.181	0.002
Alcohol levels	0.14	0.55	0.22	0.72	0.769	0.444
ISS	51.01	18.98	40.88	20.27	-3.897	<0.001

* $p < 0.05$; ** $p < 0.001$

A known psychiatric history was present in 151 out of the total number of cases (57.9%), in 116 out of 140 cases of suicides (82.8%) and in 19 out of 98 cases of accidents (19.4%). Depression, psychotic and bipolar disorders were respectively recorded in 54, 21 and 9 cases of suicidal falls representing 46.5%, 18.1% and 7.7% of the total number of suicidal fall cases with psychiatric history.

Regarding correlation analysis, age was negatively correlated with height and alcohol consumption ($p < 0.01$), height was correlated with ISS and negatively correlated with days of hospitalization, while the latest was correlated negatively with the ISS (Table 4). A stepwise multiple linear regression was performed using sex, age, psychiatric history, alcohol levels and suicidal intention as independent variables and the ISS as dependent variable. Statistically significant predictors were only psychiatric history and suicidal intention (Table 5).

Discussion

Fall from height is one of the leading causes of blunt trauma. A fall from height can be defined as the movement under the influence of gravity to a lower level than the initial due to careless behavior, lack of balance, a voluntary act of the victim or even a violent act of another person [21]. The kinetic energy gained during a fall from height results in death or severe blunt trauma as it is absorbed by the whole body during its impact with the landing surface. The trajectory, but also the launch and landing phases of the fall are important [22].

A fall from height can be an accident, a suicide act or in some cases a homicide [23–25]. Accidental falls from height are a very common cause of injury, fatal or not, especially in the extreme age groups (children, the elderly) [26]. On the other hand, jumping from a height is a common method of suicide which has some special features. For instance, the easy accessibility of this method combined with its high mortality rate, makes it very popular to people who attempt

Table 3 Injury comparison between suicidal and accidental falls using Chi-square analyses (N = 238)

	Total N = 238		Suicidal falls n = 140		Accidental falls n = 98		x ² -value	p
	n	%	n	%	n	%		
Head injuries	177	74.4%	101	72.1%	76	77.6%	0.885	0.215
Chest injuries	197	82.8%	131	93.6%	66	67.3%	27.803	< 0.01
Abdominal injuries	122	51.3%	101	72.1%	21	21.4%	59.344	< 0.01
Pelvic injuries	128	53.8%	101	72.1%	27	27.6%	46.115	< 0.01
Upper limb injuries	75	31.5%	60	42.9%	15	15.3%	20.275	< 0.01
Lower limb injuries	77	32.4%	64	45.7%	13	13.3%	27.734	< 0.01
Cervical spine injuries	99	43.4%	66	47.1%	33	33.7%	3.158	0.078
Thoracolumbar spine injuries	47	19.7%	26	18.6%	21	21.4%	0.297	0.350

to commit suicide impulsively or to frail elderly people [27–29]. Moreover, in the event of the survival of these individuals after the fall, the multiplicity and severity of the injuries they are most likely to sustain requires intensive and long-term hospitalization with multiple socio-economic consequences. For all the above reasons, it is a challenge to prevent the use of this method by people with suicidal ideation.

On this basis, it is important to outline the demographic profile of victims of falls from height in order to identify the groups of people who are prone to these falls. In our study, the majority of the victims (73.9%) were male which is in accordance with previous studies also showing male predominance with percentages ranging from 53.7 to 82.5% [9, 21, 23, 24, 30–32]. The high rate of men has been attributed to various socio-cultural and economic factors such as the fact that men tend to have riskier behavior than women and they often work in a more hazardous environment, such as the construction sector [25]. In our study, there was also a male predominance (68.4%) in victims of suicidal falls, which is also in line with other similar studies [24, 25, 30].

The age of the victims ranged between 18 and 97 years old and the mean age was 58.46 years (58.46 ± 17.45 y/o). The mean age of the victims in some studies appears to be significantly lower than in the present study. In the studies by Caki et al. [21], Obeid et al. [32], Thierauf et al. [9] and Goren et al. [30] the mean ages were 40.7, 43.5, 43.1 and 27 years, respectively. This difference can be attributed to the

fact that all these studies included victims of fatal falls under the age of 18 years old. We excluded cases of fatalities with victims under the age of 18 years old as we consider that the causal factors and the prevention strategies associated with these ages are very different. Regarding the intention of the fall, the mean age was 55.53 years in the group of suicidal falls (Group I) and 62.96 years in the group of accidental falls (Group II). So, this study demonstrates that “jumpers” were younger than “fallers” in line with the results of various other studies which also show that people who attempt suicide by jumping tend to be younger [24, 33–35].

Our study showed that in a considerable number of cases (57.9%) there was known psychiatric history. The percentages for suicidal and accidental fall cases were 82.8% and 19.4%, respectively. Depression was the most frequently reported medical condition (46.5% of the suicidal cases with psychiatric history). The spectrum of conditions encountered encompasses depression, schizophrenia, bipolar disorder, psychotic disorders, substance and alcohol dependence and abuse as well as personality disorders. The existence of a psychiatric disorder (with or without known suicidal ideation) in a person who falls from height strengthens the hypothesis that he attempted suicide. Moreover, suicide is often the epilogue of a psychiatric, sometimes undiagnosed, disorder that a person may face. Estimates for pre-existing mental illness in people who sustained suicidal falls range from 10 to 97% [28]. Nielssen et al. in a study of survivors who attempted

Table 4 Pearson’s R correlation matrix (N = 238)

	Age	Height	Alcohol levels	Hospitalization days	ISS
Age	1	-0.177**	-0.134*	-0.056	-0.092
Height	-0.177*	1	0.031	-0.179**	0.262**
Alcohol levels	-0.134*	0.031	1	-0.035	0.113
Length of hospital stay (days)	-0.056	-0.179**	0.219	1	-0.142*
ISS	-0.092	0.262**	0.113	-0.142*	1

* $p < 0.05$; ** $p < 0.001$

Table 5 Multiple linear regression using the stepwise method and dependent variable the ISS (N=238)

	β	<i>p</i>
Sex	-0.048	0.491
Age	-0.111	0.123
Psychiatric history	-0.154	0.044
Alcohol levels	0.123	0.077
Suicide	0.235	0.002
Adjusted R ²	0.062	

p > 0.05

suicide by falling from height found that 44% had a mental illness and 44% of those had not previously received psychiatric treatment [36]. This suggests that they attempted suicide on their first psychotic episode. In the study conducted by Turkoglu et al. only 15.0% of the cases had known psychiatric history [25]. This finding was attributed to the underdiagnosis of psychiatric disorders due to underestimation of their seriousness by the local society [25]. Therefore, it is probable that there is an underestimation of the coexistence of psychiatric disorders in people who attempt to commit suicide by falling from height. The reason for this underestimation can be either the underdiagnosis of psychiatric disorders or the occurrence of suicidal behavior in the early stages of a mental illness.

In our study, the height of the fall ranged between 2 and 50 m and the mean height in all fall cases was 9.35 m (9.35 ± 7.34 m). In the group of suicidal falls (Group I) the mean height (12.35 ± 8.14 m) was higher than in the group of accidental falls (Group II) (5.18 ± 3.63 m) and the difference was statistically significant ($p < 0.001$). These findings are in line with previous studies. [14, 15, 23, 25, 30, 37]

The height of fall was also correlated with ISS. This is easily explained by physics: a person at a height (*h*) above the landing surface is subjected to gravitational force (*g*) and he has a potential energy (*Pe*: $m \times g \times h$) which is converted into kinetic energy (*Ke*: $\frac{1}{2} \times m \times v^2$) during a fall. So, the height affects the velocity of a fall as it is calculated using the following formula: $v = \sqrt{2gh}$. A great amount of this kinetic energy is absorbed by the human body during the impact with the landing surface. So, the higher the fall height is, the greater the kinetic energy will be transformed, and the more severe the injuries will be [38]. Previous studies on free falls have demonstrated a higher number of injuries and body areas affected with increased fall height [8, 39, 40]. In the present study, we highlighted a positive correlation between the height in fatal falls and ISS, which provides a better assessment of the injury severity than the sole use of the location and the number of injuries.

The assessment of the severity of injuries sustained by victims of falls from height has been the subject of many

studies. In a study conducted by Topp et al., which included 4,754 cases of both suicidal and accidental falls, the severity of total injuries was greater in suicide cases, but head injuries were more severe in accidents [41]. Increased severity of injuries in suicidal falls compared with injuries reported in accidental falls was also observed in the study by Auñón-Martín et al. [42]. On the other hand, Teresiński et al. reported no statistically significant difference in the Maximum Abbreviated Injury Scores (MAIS) for each anatomical area between injuries caused after falls with suicidal intention and injuries caused after accidental falls [43]. Additionally, in the above study, no statistically significant difference was found in the overall severity of body injuries between the two groups of falls [43]. In our study, victims of suicidal falls presented higher ISS compared with victims of accidental falls. Moreover, in deaths caused by suicide, chest, abdominal, pelvic, upper, and lower limb injuries were more often observed ($p < 0.01$). No statistically significant differences were found between the two groups regarding head, cervical spine, and thoracolumbar spine injuries. Psychiatric history and suicidal intention were also highlighted as statistically significant predictors for ISS in the stepwise multiple linear regression. In the present study, victims of suicidal falls sustained more frequently injuries in all anatomical body regions (although the difference is not always statistically significant). This finding may probably be due to the fact that they fell from greater heights than victims of accidental falls.

Previous studies which dealt with the existence of a traumatic pattern in suicidal falls compared with accidental ones have shown relatively contradicting results. Richter et al. in their study on 101 patients (62 after accidental fall and 39 jumped with suicidal intention) showed no significant differences in injury patterns between accidental and suicidal high falls; however, there was a higher number of isolated injuries in all patients after unsuccessful suicidal jumps [18].

The higher frequency of lower limbs fractures in patients admitted to hospital after a suicidal fall (namely “jumpers”) is also reported in the paper by Teh et al. [14]. The study included 399 patients, 342 “fallers” and 57 “jumpers”. Injury Severity Score (ISS), death rate and number of fractures per person were higher in the group of “jumpers” [14]. Moreover, “jumpers” sustained more rib fractures (particularly on the right), pelvic and lower limb fractures, but fewer skull fractures [14]. The authors proposed that “jumpers” tend to land feet-first and then break their falls on their dominant side, sustaining thus more right-sided rib fractures.

A higher frequency of lower extremity fractures in patients who attempted suicide by fall from height has also been reported by Papadakis et al. in their study on 244 patients (180 because of an accidental fall and 64 because of a suicidal fall) admitted at a single center [17]. A significant correlation between the cause of the fall and the

presence of lower limb fractures was also showed in logistic regression analysis [17]. On the contrary, upper extremity fractures were observed most frequently in patients who had sustained an accidental fall [17]. This finding was attributed to the patients' extension of their arms in order to protect themselves [17]. The authors also found higher frequency of pelvic fractures and head and thoracic injuries in victims of suicidal high falls [17].

It must be pointed out that traumatic patterns described in autopsy studies may differ from those of studies including patients admitted to hospitals. Injuries in the last case may be less severe and located in areas less crucial for survival. Caki et al in their autopsy study (178 accidents and 23 suicides) found no statistical difference in the head-neck, anterior trunk, and pelvic injuries, but lower frequency of upper and lower extremity injuries in accidents, which was attributed to the fact that in those cases individuals fall without protection [21].

Regarding the limitations of our study, retrospective studies are often assumed to be prone to bias since the study procedures (data collection, entry, and quality assurance) are not planned ahead of time. The above problems may be overcome when the data on which the study relies have already been collected [44]. We believe that in our study, selection bias was not an issue. First of all, the total number of fatal falls from height are submitted to complete autopsy (independently of the suicidal or accidental cause of fall). Then, our sample consisted of consecutive cases, so that all the autopsy cases of falls from height performed in our Department were collected. Finally, since data collection and autopsies were not performed by the same forensic pathologists, the procedure could be considered as a blind one. Besides, the cases included in our study represent all the fatal falls from height in a population area of approximately 1,000,000 people, who account for about 1/10 of the total Greek population [19].

A limitation of the study was the high variance in the results, mainly concerning the length of hospital stay. Even though most cases met an instantaneous death, a few cases were hospitalized for 15–120 days. The aforementioned outliers conclude to a higher variance, affecting the standard deviation.

The forensic investigation of a fall from height is a quite challenging procedure. When reconstructing the possible sequence of events and the manner of death in a fatal case of fall from height, every single information available is valuable. Of course, clear conclusions cannot be derived by isolated data (for example the height of fall), however, the careful consideration and integrated approach of all aspects (medical history, height of fall, distribution, multiplicity and severity of injuries, demographic characteristics of the victim, location of fall, e.t.c.) in accordance with the existing

literature is of paramount importance. In that sense, we believe that our conclusions, although limited to fatal cases, are highly important for death statistics and forensic research and practice.

Conclusions

This study confirms that there are differences in the profile of the victims and in the severity of injuries caused by falls from height depending on the intention of the victim. In our sample, victims of suicidal falls were younger, they usually had a previous psychiatric history, they fell from higher heights, and they sustained more severe injuries compared with victims of accidental falls. Victims who committed suicide by jumping from height had significantly greater overall severity of body injuries (as it was demonstrated by ISS). Injuries in the thorax, abdomen, pelvis, upper and lower extremities were more frequently observed after a suicidal fall, probably due to the greater height of fall. A distinct pattern of injuries in victims of suicidal falls was not demonstrated.

Key points

1. In our study, victims of suicidal falls were younger, they usually had a previous psychiatric history and they fell from higher heights.
2. Victims who committed suicide by jumping from height had significantly greater overall severity of body injuries (as it was demonstrated by ISS).
3. Injuries in the thorax, abdomen, pelvis, upper and lower extremities were more frequently observed after a suicidal fall, probably due to the greater height of the fall.
4. A distinct pattern of injuries in victims of suicidal falls compared with victims of accidental falls was not demonstrated.

Authors' contributions MT was responsible for the collection and interpretation of data, and she participated in drafting and writing the article. AD performed the evaluation of the toxicological results and she participated in drafting and writing the article. AA and ES performed the statistical analysis and evaluated the results. IP participated in the conception of the study, and he participated in drafting and writing the article. NG, CS and SP participated in the conception and design of the study and revised the article for critically important intellectual content. NG, CS and SP had also performed the autopsies. All the authors approved the final version to be published.

Data availability All data generated or analyzed during this study are included in this published article or are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Ethics approval and consent to participation The Department of Forensic Medicine and Toxicology of the National and Kapodistrian University of Athens is authorized to perform the forensic investigation of more than one third of violent and sudden deaths occurring in Attica (Athens metropolitan area). The study was approved by the Ethics Committee of the National and Kapodistrian University of Athens.

Patient consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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