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Research Paper

Relationship of injuries detected in fatal falls with sex, body mass index, and fall height: An autopsy study

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ABSTRACT

Falls from height are the most common cause of blunt trauma after traffic accidents. The focus of this retrospective study was to analyze the relationship between injuries in fatal falls and fall height, body mass index (BMI), and sex in 206 autopsy reports. Age, sex, weight, height, place of the fall, fall height, period between the incidence and death, external examination findings in the autopsy, intracranial findings, fractures, internal organ injuries, and information about the causes of death were recorded. Accidents and men were the largest groups. Injuries to the upper and lower extremities were frequently detected in accidents. Lower extremity injuries were more common in women. The occurrence of head and neck injuries were rare in overweight individuals. When evaluated by manner of death, there were differences in extremities and posterior body injuries. There was no difference between sex in terms of autopsy findings. It was observed that the injuries increased as the height increased. There was a statistical difference between the BMI groups in terms of liver, rib and sternum injuries. The most common cause of death was head injuries. Many factors have been known to affect injury patterns in cases of falls from height. Fall height, BMI, and gender are just a few of these factors. This study will be beneficial to support the findings of this study with larger-scale studies and statistical modeling that consider more factors affecting injuries in cases of falls.

1. Introduction

Falls from height can be defined as the movement to a level below the current level by the influence of gravity due to carelessness, imbalance, or voluntary action of one's self or another. The kinetic energy gained during falls from heights causes serious traumatic injuries and death by affecting the whole body when it hits the ground.

Due to high morbidity and mortality rates of traumas caused by falls from height, they are important for clinical and forensic practices. Falls from height are the most common cause of blunt trauma after traffic accidents.[1,2] Falls from height frequently encountered in the cities are among the most common three causes of death due to trauma. The mortality rates in the USA and England are 5.1 and 7.1 in 100,000, respectively.[3,4] Many variables, such as age, sex, body structure, bone density, fall angle, fall height, ground feature, and first contact side of the victim affect the injuries and cause of death in falls from height.[5]

The focus of this retrospective study was to analyze the relationship between injuries in fatal falls and fall height, body mass index (BMI), and sex on 206 autopsy reports.

2. Materials and methods

2.1. Sample universe

The sample universe of this retrospectively planned study is the mortality cases sent to The First Forensic Medicine Specialized Board at the Council of Forensic Medicine in Istanbul.

Cases with undetermined cause of death are discussed in the First Forensic Medicine Specialized Board comprises of forensic experts and clinicians. The Board may decide on causes of deaths other than ICD (International Classification of Diseases) and more than one cause of death. Multiple causes of death indicate comorbidity.

2.2. Case preference

From the board archives, reports between 2011 and 2015 were reviewed, and 206 files of deaths caused by falls from height were included in the study.

Age, sex, weight, height, place of the fall, fall height, period between

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the incidence and death, external examination findings in the autopsy, intracranial findings, fractures, internal organ injuries, and information about the causes of death were recorded.

When the fall height was expressed in terms of floor, the height of one floor was assumed as 3 m.

Cases with >75% coronary stenosis and no other fatal injuries were considered cardiac death.

2.3. Exclusion criteria

The cases of falls from the same height, falls from any vehicle type (crane, elevator, etc.), falls from ladders, cases subjected to secondary traumas (for example a traffic accident after fall from the bridge, etc.) were considered. Because the examination findings may be misleading, cases wherein the time between fall and death was >30 days and not autopsied timely were excluded.

Rib and sternal fractures and lung contusions due to cardiopulmonary resuscitation were also excluded.

2.4. Statistical analysis

Research data were analyzed using descriptive statistics, Chi-squared, Mann–Whitney U, correlation, and logistic regression tests by using the SPSS 21 (IBM Corp., Armonk, NY, USA) statistics program.

2.5. Ethical aspects

Ethical approval was obtained from the institutional ethical committee before the study.

3. Results

Of 206 cases, 170 (82.5%) and 36 (17.5%) were that of men and women, respectively, with a mean age of 40.7 ± 1.6 years. The mean time of death was 5.4 ± 0.5 days after falling, with a median value of 1.0 day, and the mean fall height was 8.2 ± 0.7 m. Although the most frequent falls were from balconies (18.6%) and buildings (18.6%), the most common places were buildings (21.6%) and balconies (31.3%) for men and women, respectively (Table 1). When the manner of death was compared according to sex, it was seen that males had proportionally more accidents and this situation was statistically significant (Table 2).

For the regional examination of external regions, the body was divided into six regions: the head–neck, lower extremity, upper extremity, anterior trunk, posterior trunk, and pelvic region. The most common injuries were found in the head–neck region (62.1%), and only the lower extremity injuries were statistically different between men and women (p = 0.002) (Fig. 1). BMI was statistically significant only in head and neck injuries (p = 0.001) (Fig. 2). Based on the manner of death, no statistical significance was found in head–neck and anterior trunk injuries, but a statistically significant difference was found in posterior trunk and upper and lower extremity injuries (Table 3).

Although 34.1% of the cases had subarachnoid hemorrhages, the most common bone fracture was in the ribs (42.4%), and the most frequently injured internal organ was the lungs (25.2%). No statistically significant difference was found in autopsy findings between sex (Table 4). There was a statistically significant difference between BMI groups in rib, sternum fractures and liver injuries. (Table 5).

In cases of increased height, the frequency of subarachnoid hemorrhage, cerebral contusion, cranial dome fracture, skull base fracture, rib fracture, sternal fracture, and lung, liver and spleen ruptures were increased (Table 6).

Regression analysis was used to determine the relationship between sex and changes in height at 10-m intervals. Findings were shown in Table 7.

Regression analysis was also used to determine the relationship between BMI and changes in height at 10-m intervals. Findings were shown in Table 8.

The most common causes of death were head trauma (37.4%), followed by internal organ injury (36.4%) and fractures and complications (26.2%), whereas more than one causes of death were determined in the 37.4% (n = 77) of the cases. A significant part of deaths (4.4%) being cardiac in origin (pathological) was found to be noteworthy. No statistically significant difference in mortality was found between male and female cases (Table 9).

Table 1
Location of fall.

Place	Male		Female		Total	
	n	%	n	%	n	%
Balcony	26	16.0	10	31.3	36	18.6
Buildings	35	21.6	1	3.1	36	18.6
Tree	14	8.6	6	18.8	20	10.3
Roof	18	11.1	1	3.1	19	9.8
Window	10	6.2	4	12.5	14	7.2
Wall	9	5.6	0	0.0	9	4.6
Pole	7	4.3	0	0.0	7	3.6
Cliff	3	1.9	4	12.5	7	3.6
Lift Clearance	7	4.3	0	0.0	7	3.6
Bridge	4	2.5	2	6.2	6	3.1
Stairwell	5	3.1	0	0.0	5	2.6
Other	24	14.8	4	12.5	28	14.4
Total	162	100.0	32	100.0	194	100.0

*12 cases without recorded location information are not included in the table.

Table 2
Manner of death.

Manner of Death	Male		Female		Total	
	n	%	N	%	n	%
Accident	153	90.0	25	69.4	178	86.4
Suicide	15	8.8	8	22.2	23	11.2
Homicide	2	1.2	3	8.3	5	2.4
Total	170	100.0	36	100.0	206	100.0
p = 0.002						

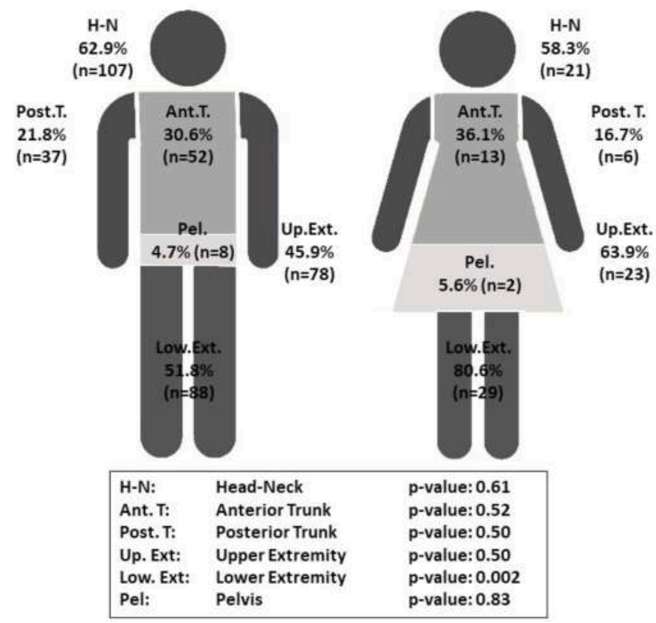

Fig. 1. Localization of injuries detected in external examination and sex.

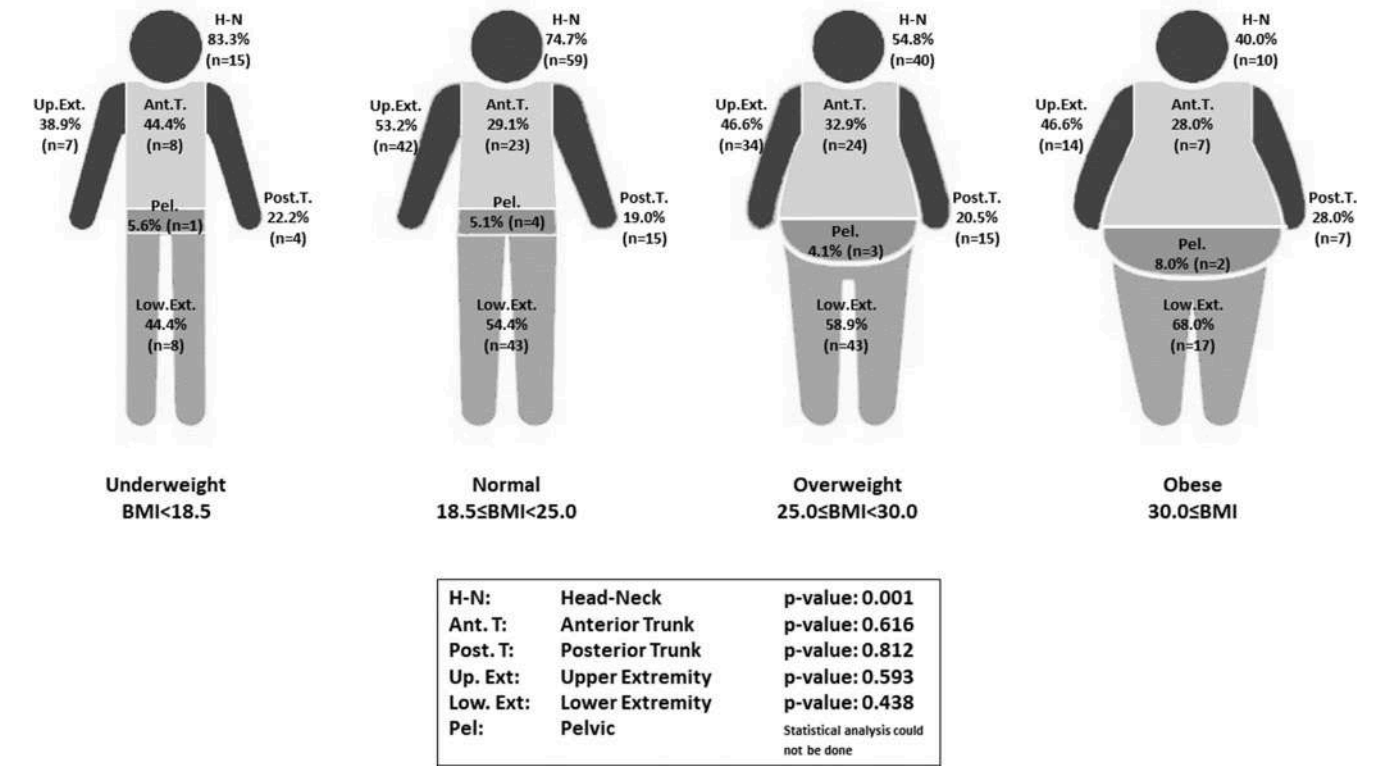

Fig. 2. Localization of injuries detected in external examination and BMI.

Table 3
Localization of injuries detected in external examination and manner of death.

Localization	Accident		Suicide		Homicide		Total		p value
	n	%	n	%	n	%	n	%	
Head-Neck	107	60.1	17	73.9	4	80.0	128	62.1	0.310
Lower Extremity	**93**	**52.2**	**21**	**91.3**	**3**	**60.0**	**117**	**56.8**	**0.002**
Upper Extremity	**80**	**44.9**	**18**	**78.3**	**3**	**60.0**	**101**	**49.0**	**0.010**
Anterior Trunk	51	28.7	12	52.2	2	40.0	65	31.6	0.068
Posterior Trunk	**33**	**18.5**	**7**	**30.4**	**3**	**60.0**	**43**	**20.9**	**0.039**
Pelvic Region	8	4.5	2	8.7	0	0.0	10	4.9	–

4. Discussion

In this study, a significant percentage of the cases were male (82.5%). Male predominance was also found in the studies by Gören et al. (61.2%), Beale et al. (82%), Obeid et al. (76.6%), and Kusior et al. (65.7%).[6–9] The male predominance in this study was consistent with the literature, considering that men are exposed to higher levels of fall from height than women because men more frequently work at jobs at higher elevations.

Cases occurred mainly as falls from balconies (18.6%), buildings (18.6%), and trees (10.3%). In the study by Gören et al., the roof, balcony, and stairs were the most common places for falls, whereas that by Yavuz et al. indicated that the three most frequent places for falls were balconies, buildings, and staircases, respectively.[6,10] However, in the study by Gulati et al., the three most common places for falls were rooftops, wooden ladders, and trees.[11] Because the most common places for falls from height were buildings and balconies, which was consistent with the previous literature, the importance of following procedures and practices related to occupational health and safety of workers particularly working in these areas was highlighted.

The age range was between newborn and 87 years, and the mean age was 40.7 years. The mean ages in the study by Gören et al., Obeid et al., Gulati et al., Petaros et al., and Atanasijevic et al. were 27, 43.5, 31.3, 55, and 44.7 years, respectively.[6,8,11–13] The diverse age range of the high fall cases in the previous studies indicate that falls from height can cause serious injuries and deaths worldwide at every age.

One of the most important factors affecting mortality in this study was height at 8.2 m. Kohli et al. showed that the mean height of the cases ranged between 3 and 6 m, corresponding to 62.9% of the cases.[14] Furthermore, Koyun showed that deadly falls often (42.8%) occur after falling from height between 6 and 7.9 m, whereas Risser et al. and Icer et al. showed that the mean fall height was 16.9 and 6.61 m, respectively.[4,15,16] The mean height of fatal falls in this study was consistent with that in the literature.

According to the literature, 50% of the patients died at the time of accident, 30% of them died within the first 24 h after the trauma, and the remaining 20% died after the first day of accident. Early diagnosis and treatment within the 24 h following the accident have been reported to reduce the mortality to 2%–9%.[4,14,17] In our study, the mean post-event survival of patients falling from height was 5.4 days, with a median of 1 day, showing that death occurred in the early stage.

Based on the manner of death, no statistical difference was found in the head–neck, anterior trunk, and pelvic injuries. However, upper and lower extremity injuries were observed less frequently in accidents because individuals fall without protection. There was no statistically significant difference in external examination findings between men and

Table 4
Comparison of autopsy findings and sex.

Injury	Male		Female		Total		p value
	n	%	N	%	n	%	
Intracranial Findings							
Subarachnoid Hemorrhage	58	34.1	18	50.0	76	36.9	0.73
Subdural Hemorrhage	26	15.3	6	16.7	32	15.5	0.84
Epidural Hemorrhage	15	8.8	3	8.3	18	8.7	0.92
Cerebral Contusion	30	17.7	5	13.9	35	17.0	0.59
Dome Fracture	50	29.4	9	25.0	59	28.6	0.60
Skull Base Fracture	45	26.5	10	27.8	55	26.7	0.87
Fractures							
Rib	72	42.4	13	36.1	85	41.3	0.49
Vertebra	59	34.7	16	44.4	75	36.4	0.27
Lower Extremity	38	22.4	5	13.9	43	20.9	0.26
Sternum	23	13.5	6	16.6	29	14.1	0.62
Pelvis	31	18.2	6	16.7	37	18.0	0.82
Upper Extremity	29	17.1	2	5.6	31	15.0	0.08
Facial Bone	8	4.7	0	0.0	8	3.9	0.18
Hyoid	4	2.4	0	0.0	4	1.9	0.35
Internal Organ Lesions							
Lung	31	18.2	5	13.9	36	17.5	0.53
Liver	22	12.9	6	16.7	28	13.6	0.55
Spleen	16	9.4	3	8.3	19	9.2	0.84
Kidney	10	5.9	3	8.3	13	6.3	0.59

*Since the number of cases with heart, large artery, gastrointestinal and pancreatic injuries were not sufficient, statistical evaluation could not be performed.

women, except for the lower extremity. It was thought that lower extremity injuries in men were less frequent, because men had more accidents. As BMI increased, the incidence of head and neck injuries on external examination decreased, which may be due to the body's center of gravity being closer to the head in underweight individuals.

Cirak et al. showed that 44% of head traumas were caused by falls from height, and the morbidity and mortality rates could significantly be reduced by early interventions.[18] In this study, 36.9% of the cases had subarachnoid hemorrhage, 15.5% had subdural hemorrhage, 8.7% had epidural hemorrhage, 17.0% had cerebral contusion, 31.7% had skull base fractures, and 28.4% had cranial dome fractures. The most common intracranial hemorrhage was subarachnoid hemorrhage because it is the most common type of bleeding in all types of trauma. Similarly, Beale et al. showed that the ratio of skull base and cranial dome fractures was 34.8% and 31.5%, respectively.[7] In addition, Kohli et al. reported that the ratio of skull base and cranial dome fractures was 41.8% and 37%, respectively, and Bruno et al. reported those at 45% and 36%, respectively.[14,19] Although skull fractures were found less in our study, it was found that skull base fractures were more common than dome fractures, similar to other studies.

When intracranial findings were analyzed with regards to the height, the frequency of dome fracture, skull base fracture, subarachnoid hemorrhage, and cerebral contusion increased as the height increased. In the study by Obeid, cases of falls from height were divided into five groups based on heights at 25-feet intervals (7.62 m), indicating a significant difference between the groups in terms of head fractures and intracranial hemorrhages.[8] Thierauf et al. showed that the occurrence of intracranial findings decreased as height increased, and cerebral laceration and fractures tended to occur more frequently at lower heights.[20] The findings of this study were consistent with the literature as the increase in the height leads to the likelihood of occurrence of intracranial findings.

The frequency of fractures varies based on the condition of the body part upon first contact after the fall. In our study, the most common bone fracture was rib fractures (41.3%), followed by vertebral fracture (35.8%). Bruno et al. reported that 92% and 46% of the fractures were rib and sternal fractures, respectively.[19] Petaros et al. showed that the most common fractures were sternal fractures (73%), followed by vertebral fractures (40%).[12] By contrast, Venketesh et al. showed that 51.2% and 32.5% of the fractures were rib and lower extremity fractures, respectively.[21] Some differences were found between the rates of the most common fractures among the studies, and our results were similar to those of the study by Petaros et al. The proportional differences among the other studies were thought to depend on the fall positions of the cases.

With regard to the relationship between occurrence of fractures and height, the risk of rib and sternal fractures increased as height increased, and no such relationship was found for other fractures. In the study by Bruno, cases of fall from heights were divided into falls from <12 to >12 m, and no significant difference was found between the two groups in terms of rib, sternal, and clavicular fractures.[19] In the study by Obeid, a significant difference was found in the rib and pelvic fractures between five groups, although no significant differences were found in the sternal and cervical spine fractures.[8] In the study by Petaros, falls from height were divided into four groups: 1–3.5 m, 4–10 m, 10.5–30 m, and ≥30.5 m, and clusters of fractures in a particular body region were evaluated regardless of the number of fractures. In the lowest height group (1.5–3.5 m), 88% of the cases had fractures at the upper and middle parts of the body, and the highest height group (>30.5 m) showed that

Table 5
Comparison of autopsy findings and BMI.

Lesion	Underweight		Normal		Overweight		Obese		p value
	n	%	n	%	n	%	n	%	
Intracranial Findings									
Subarachnoid Hemorrhage	10	55.6	31	39.2	24	32.9	8	32.0	0.31
Subdural Hemorrhage	6	33.3	13	16.5	8	11.0	5	20.0	0.13
Epidural Hemorrhage	2	11.1	7	8.9	4	5.5	4	16.0	0.43
Cerebral Contusion	3	16.7	19	24.1	9	12.3	3	12.0	0.24
Dome Fracture	6	33.3	30	38.0	15	20.5	4	16.0	0.05
Skull Base Fracture	6	33.3	25	31.6	16	21.9	5	20.0	0.42
Fractures									
Rib	**2**	**11.1**	**33**	**41.8**	**33**	**45.2**	**14**	**56.0**	**0.03**
Vertebra	3	16.7	28	35.4	32	43.8	10	40.0	0.19
Lower Extremity	1	5.6	13	16.5	19	26.0	9	36.0	0.05
Sternum	**0**	**0.0**	**8**	**10.1**	**14**	**19.2**	**7**	**28.0**	**0.03**
Upper Extremity	3	16.7	11	13.9	14	19.2	3	12.0	0.78
Internal Organ Lesions									
Lung	2	11.1	15	19.0	14	19.2	5	20.0	0.87
Liver	**5**	**27.8**	**9**	**11.4**	**14**	**19.2**	**0**	**0.00**	**0.03**
Spleen	1	5.6	8	10.1	9	12.3	0	0.0	0.29
Kidney	3	16.7	8	10.1	2	2.7	0	0.0	0.05

*Since the number of cases with pelvic bone, facial bone, hyoid bone, heart, large artery, gastrointestinal and pancreatic injuries were not sufficient, statistical evaluation could not be performed.

Table 6
Comparison of height changes and autopsy findings.

Localization	Injury	Average Height (m)	Standard Error	p value
Intracranial Findings				
Subarachnoid Hem.	+	**11.15**	**1.47**	**0.001**
	-	**6.38**	**0.62**	
Subdural Hem	+	11.47	3.39	0.06
	-	7.61	0.59	
Epidural Hem.	+	12.47	5.84	0.08
	-	7.81	0.60	
Cerebral Contusion	+	**12.74**	**1.76**	**0.003**
	-	**7.23**	**0.73**	
Dome Fracture	+	**10.53**	**1.66**	**0.009**
	-	**7.07**	**0.65**	
Skull Base Fracture	+	**11.23**	**1.84**	**0.003**
	-	**6.98**	**0.62**	
Fracture				
Rib	+	**10.85**	**1.28**	**<0.001**
	-	**5.94**	**0.60**	
Vertebra	+	7.87	1.04	0.84
	-	8.28	0.90	
Upper Extremity	+	10.09	2.11	0.40
	-	7.80	0.73	
Lower Extremity	+	8.30	1.03	0.25
	-	8.11	0.84	
Pelvis	+	10.39	1.58	0.07
	-	7.63	0.77	
Sternum	+	**13.41**	**3.18**	**0.002**
	-	**7.25**	**058**	
Internal Organ Injuries				
Lung	+	**12.87**	**1.82**	**0.001**
	-	**7.10**	**0.71**	
Liver	+	**13.13**	**1.85**	**<0.001**
	-	**7.20**	**0.72**	
Spleen	+	**14.82**	**2.32**	**<0.001**
	-	**7.33**	**0.69**	

*Since the number of cases with facial and hyoid bone fractures and heart, kidney, large vessel, gastro-intestinal and pancreatic injuries were not sufficient, statistical evaluation could not be performed.

Table 7
Evaluation of relationship of autopsy findings with gender and height.

Variable	**p value**	**Exp (B)**	%95 C.I.for Exp (B)	
			Lower	**Upper**
Subarachnoid Hem.				
Sex	**0.008**	**0.261**	**0.098**	**0.700**
10 m	**0.002**	**2.501**	**1.412**	**4.429**
Epidural Hem.				
Sex	0.593	0.718	0.213	2.420
10 m	**0.012**	**1.972**	**1.158**	**3.357**
Dome Fracture				
Sex	0.722	0.834	0.308	2.262
10 m	**0.034**	**1.686**	**1.040**	**2.731**
Skull Base Fracture				
Sex	0.179	0.508	0.189	1.365
10 m	**0.013**	**1.913**	**1.149**	**3.184**
Rib Fracture				
Sex	0.903	1.062	0.406	2.777
10 m	**0.001**	**2.935**	**1.539**	**5.596**
Sternal Fracture				
Sex	0.845	0.874	0.227	3.365
10 m	**0.011**	**2.035**	**1.177**	**3.518**
Lung Injury				
Sex	0.728	0.807	0.241	2.701
10 m	**0.007**	**2.095**	**1.219**	**3.603**
Liver Injury				
Sex	0.186	0.458	0.144	1.457
10 m	**0.008**	**2.114**	**1.216**	**3.677**
Spleen Injury				
Sex	0.973	0.972	0.197	4.798
10 m	**0.010**	**2.154**	**1.204**	**3.853**

*Only injuries with statistical differences are presented.

Table 8
Evaluation of relationship of autopsy findings with gender and height.

Variable	p value	Exp (B)	%95 C.I.for Exp (B)	
			Lower	Upper
Subarachnoid Hem.				
Underweight	0.955			
Normal	0.723	1363	0.245	7.590
Overweight	0.838	1.135	0.335	3.842
Obese	0.932	0.947	0.269	3.335
10 m	**0.002**	**2.514**	**1.400**	**4.515**
Subdural Hem.				
Underweight	0.245			
Normal	0.671	0.661	0.098	4.471
Overweight	0.213	0.430	0.114	1.622
Obese	**0.048**	**0.218**	**0.048**	**0.986**
10 m	0.120	1.548	0.892	2.685
Epidural Hem.				
Underweight	0.140			
Normal	0.451	0.400	0.037	0.913
Overweight	0.056	0.200	0.038	1.045
Obese	**0.040**	**0.146**	**0.023**	**0.913**
10 m	0.232	1.435	0.794	2.595
Cerebral Contusion				
Underweight	0.421			
Normal	0.999	0.000	0.000	–
Overweight	0.462	1.809	0.373	8.783
Obese	0.695	0.711	0.129	3.918
10 m	**0.011**	**2.146**	**1.195**	**3.851**
Dome Fracture				
Underweight	0.220			
Normal	0.591	1.661	0.261	10.571
Overweight	0.192	2.438	0.638	9.312
Obese	0.979	1.019	0.249	4.164
10 m	**0.017**	**1.824**	**1.113**	**2.988**
Skull Base Fracture				
Underweight	0.567			
Normal	0.955	0.944	0.125	7.151
Overweight	0.403	1.792	0.457	7.032
Obese	0.994	1.005	0.241	4.199
10 m	**0.009**	**2.002**	**1.191**	**3.366**
Rib Fracture				
Underweight	0.080			
Normal	0.013	0.041	0.003	0.506
Overweight	0.109	0.380	0.116	1.241
Obese	0.116	0.377	0.112	1.272
10 m	**0.001**	**3.028**	**1.549**	**5.919**
Sternal Fracture				
Underweight	0.605			
Normal	0.999	0.000	0.000	–
Overweight	0.286	0.441	0.098	1.984
Obese	0.869	0.886	0.210	3.729
10 m	**0.023**	**1.951**	**1.096**	**3.472**
Lung Injury				
Underweight	0.514			
Normal	0.887	1.221	0.076	19.521
Overweight	0.358	2.473	0.359	17.057
Obese	0.203	3.472	0.510	23.620
10 m	**0.006**	**2.025**	**1.227**	**3.433**

*Only injuries with statistical differences are presented.

most of the fractures (61%) had widespread distribution throughout the body.[12] Although some differences were found our study results and those of the abovementioned studies due to the height changes considered in the evaluations, the results were generally consistent with the literature.

Because the stomach and intestines are relatively movable organs, the kidney is in the retroperitoneal area, and the adipose tissue provides cushion effect, they are more rarely injured than other internal organs caused by blunt traumas.[19] In our study, the most commonly injured organ was the lung (25.2%), followed by the liver (16.6%) and spleen (8.5%). In the study by Bruno et al., the lung (76%) was the most frequently injured organ, followed by the liver (58%).[19] In a study by Çetin et al., lung lobe laceration, lung hilum laceration, liver injury, and splenic injury were found in 40%, 40%, 35%, and 30% of the cases,

Table 9
Cause of death.

Cause of Death[a]	Male		Female		Total		p value
	n	%	n	%	n	%	
Head Trauma	60	35.3	17	47.2	77	37.4	0.18
Internal Organ Injury	59	34.7	16	44.4	75	36.4	0.27
Fractures and Complications	46	27.1	8	22.2	54	26.2	0.55
Spinal Cord Injury	28	16.5	10	27.8	38	18.4	0.11
Major Artery Injury	9	5.3	2	5.6	11	5.3	0.95
Cardiac (Pathological)	8	4.7	1	2.8	9	4.4	0.61
Drowning	6	3.5	2	5.6	8	3.9	0.57
Pneumonia	6	3.5	1	2.8	7	3.4	0.82
Other	16	9.4	1	2.8	17	8.3	0.08

[a] Since more than one cause of death can be found in the files, the total is over 100%. In our system multiple causes of death mean comorbidity.

respectively.[22] In the study by Atanasijevic et al., the liver and lung injury rates were 37.6% and 28.3%, respectively.[13] In the study by Türk et al., lung, heart, and liver injuries were found in 79%, 54%, and 54% of the cases, respectively.[3] In the literature, the injury rates had a wide range, and our study findings were within this range. Likewise, the lungs were observed as the most frequently injured organ in fatal high falls in accordance with the literature. The most commonly injured organ was the lung and it is thought that it is damaged the most due to the principle of inertia of the lung, which is not attached to any other structures than the hilum due to its anatomical structure.

In the comparison between incidence of internal organ injuries and height changes, lung, liver, and spleen injuries were statistically associated with height. By contrast, Atanasijevic et al. reported that lung injury, hemothorax, and aortic and heart rupture frequency were not statistically correlated with fall height.[13] In the study by Bruno et al., statistically significant differences were found in heart, lung parenchyma, thoracic aorta, diaphragm, and liver injuries between the two groups in cases of fall from the heights that were >12 and < 12 m, whereas lung hilum, spleen, superior vena cava, esophagus, pancreas, stomach, kidney, bladder, and small and large intestinal injuries did not differ significantly depending on the height.[19] Obeid et al. reported significant differences in liver, spleen, lung, and kidney injuries between the five groups with 25-feet intervals in height between each group.[8] Our study results were similar with those by Obeid in terms of internal organ injuries and elevation relationship. We believe that the differences between the results of other studies and this study are due to other factors affecting internal organ injuries besides the fall height.

In this study, the most common causes of death were head trauma (37.4%) and internal organ injury (36.4%), and the majority of cases (62.6%) had more than one cause of death, which was consistent with other studies. In the study by Türk et al., the mortality rates related to polytrauma and head trauma were 44.1% and 33.8%, respectively.[3] By contrast, Al et al. reported that head trauma was observed in all cases of fall from height resulting in death.[23] Because the cases of falls from height are traumas that involve more than one system, and 62.6% of cases have more than one cause of death, the cases of falls from height should be evaluated as multidisciplinary conditions. In addition, because the cause of death in 4.4% was cardiac in origin, the possibility of the presence of pathological disease even in cases of falls from height should not be ignored.

In Obeid's study, a statistically significant difference was observed in non-cervical vertebra and rib fractures between BMI groups.[8] In Rowbotham's study, in which bone fractures in falling from height were evaluated, it was found that there was only a difference in pelvis and rib fractures between BMI groups.[24] In this study, rib and sternum fractures were observed more frequently in overweight individuals. This situation was similar to the literature. It was thought that different distribution of adipose tissue and bone problems in overweight individuals may cause this. In addition, it was thought that the lower frequency of liver injuries in overweight individuals may be due to the protective effect of adipose tissue.

In the study of Petaros found no statistical difference between genders in any bone.[12] In contrast, Obeid et al. Reported that there are statistical differences between the sex. Intracranial bleeding was more common in men (%64) than in women (%53). But it was observed that liver injury (66%–53%), cervical vertebra (19%–10%), rib (87%–77%) and pelvis fractures (62%–48%) were more common in women. In the study of Obeid, this situation was thought to be due to the different body structure of men.[8] In this study, no significant difference was found between sex in terms of autopsy findings.

Logistic regression analysis was used to evaluate the relationship between sex or height changes and various parameters, independent of sex, which showed that for every 10-m height increase, the incidence of subarachnoid hemorrhages, epidural hemorrhages, cranial dome fractures, skull base fractures, rib fractures, sternal fractures increased by 2.501, 1.972, 1.686, 1.913, 2.935, and 2.035 times, respectively, and lung, liver, and splenic injuries were increased by 2.095, 2.114, and 2.154 times more frequent, respectively.

Regression analysis was also used to determine the relationship between BMI and changes in height at 10-m intervals. It was determined that subdural and epidural hemorrhages occurred more frequently in overweight individuals in a statistically significant way. No statistically significant differences were found in subarachnoid hemorrhages, cerebral contusion, dome fracture, skull base fracture, rib fracture, sternal fracture and lung injury between BMI; however, the frequency of the abovementioned injuries increased 2.514, 2.146, 1.824, 2.002, 3.028, 1.951 and 2.025 times, respectively, at every 10-m increase in height.

Although significant results are detected in the evaluations with logistic regression analyzes, it should be taken into account that there are many variables that will affect the injuries caused by falling from height.

We believe that the frequency of formation of body injuries according to height increase can be possibly determined with the help of new studies about the subject and this study, and knowledge of the fall height will possibly guide the examination and imaging methods of the injuries in forensic practice.

4.1. *Limitations*

Our study has several limitations. Situations alleged by crime scene teams were considered in the manner of death assessment, but these may be erroneous. In murder cases, it was accepted that the patient did not die before the fall. The features of the fall surface and drop angle were unknown. All these situations will change the characteristics of injury and the cause of death.

5. Conclusion

Many factors affect injuries in cases of falls from height. Fall height, BMI, and gender are just a few of these factors. As the height increased, the injuries were caused increased due to the increased kinetic energy. The difference between the BMI groups was thought to be due to the protective effect of fatty tissue and the change in body center of gravity. This study will be beneficial to support the findings of this study with larger-scale studies and statistical modeling that consider more factors affecting injuries in cases of falls.

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Declaration of competing interest

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