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# Evaluation of Severity Score in Patients with Lower Limb and Pelvic Fractures Injured in Motor Vehicle Front-Impact Collisions

Authors' Contribution:  
Study Design A  
Data Collection B  
Statistical Analysis C  
Data Interpretation D  
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Literature Search F  
Funds Collection G

ABCDEF 1 **Mehmet Ata Gokalp**  
ABC 2 **Yavuz Hekimoglu**  
BFG 1 **Abdurrahim Gozen**  
DEF 1 **Savas Guner**  
ABCDEF 2 **Mahmut Asirdizer**

1 Department of Orthopedics and Traumatology, Yuzuncu Yil University, Medical Faculty, Van, Turkey  
2 Department of Forensic Medicine, Yuzuncu Yil University, Medical Faculty, Van, Turkey

**Corresponding Author:** Mahmut Asirdizer, e-mail: [masirdizer@yahoo.com](mailto:masirdizer@yahoo.com)  
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**Background:** Lower limb and pelvic injuries and fractures occur at a very high incidence in motor vehicle accidents. In this study, the characteristics (e.g., body side, bone location, and fracture severity) of lower limb and pelvic fractures that occurred during front-impact collisions were correlated with the injured patients' sex, age, and position in the vehicle.





**Material/Methods:** We retrospectively evaluated 191 patients (136 males, 55 females) who were injured in motor vehicle accidents, specifically in frontal collisions.

**Results:** This study revealed that most of lower limb and pelvic fractures occurred in males (71.2%;  $p=0.000$ ), 19–36 years old (55.5%;  $p=0.000$ ), small vehicles (86.4%;  $p=0.000$ ), and rear seat passengers (49.2%;  $p=0.000$ ). Fractures most commonly occurred in the left side of the body (46.6%;  $p=0.000$ ) and upper legs (37.7%;  $p=0.000$ ). Severity scores were higher (2.76) in males than females (2.07). No statistically significant was found in severity scores of patients and other personal characteristics and fracture features of patients with lower limb and pelvic fractures who were injured in a vehicle during front-impact collisions ( $p>0.05$ ).

**Conclusions:** The results of this study will be useful for the automobile industry, forensics and criminal scientists, and for trauma research studies.

**MeSH Keywords:** **Accidents, Traffic • Fractures, Bone • Injury Severity Score**

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## Background

Today, motor vehicle accidents are one of the most important health problems in the world, and they have a high morbidity and mortality rate. The number of motor vehicle accidents continues to rapidly grow in parallel with the increase in population and vehicle numbers. Each year nearly 1.3 million people die and 20–50 million people sustain non-fatal injuries caused by motor vehicle accidents throughout the world [1]. According to data from the National Police of Turkey, 41 454 people died and 2 175 608 people were injured in 10 214 885 motor vehicle accidents in Turkey during the last decade (between 2005 and 2014) [2].

Previous studies have reported a correlation between trauma localization and the in-vehicle position of people injured in motor vehicle accidents [3]. Many authors have conducted studies on the subject of driver and passenger crash injury using severity models [3,4]. In these studies, certain factors, such as age, sex, seat belt use, vehicle type, airbags, accident type, impact point, and vehicle speed, were associated with the localization and severity of the injury [3,4].

In recent studies, lower limb and pelvic injuries and fractures were shown to often occur in motor vehicle accidents, especially in drivers in front-impact collisions and in pedestrians [3,5,6]. The type of fractures of the lower limb and pelvis in motor vehicle accidents was reported in some of the studies [6]; however, these studies are limited. In the present study, we aimed to investigate body side, bone location, and severity score (SS) according to Turkish Fracture Severity Scale (TFSS) of lower limb and pelvic fractures that occurred during front-impact collisions and to correlate the SS with the injured patients' characteristics and fracture features.

## Material and Methods

In this study, data were collected in 2 stages. During the first stage, the medical records of patients with lower limb and pelvic fractures that were injured in front-impact collision accidents were retrospectively reviewed. These patients were referred to the Orthopedics and Traumatology Sections and Forensic Medicine Section of Dursun Odabas Medical Center of Yuzuncu Yil University (Van, Turkey) between 01 January 2010 and 31 December 2014. Patients transferred to intensive care units and other clinics due to concomitant injuries in head, thorax, and/or abdomen were not evaluated in this article because it was not possible to access all information about the features of their motor vehicle accidents. For patients who were included in the study, demographic features were recorded, and the fracture locations and the long bone fracture type were defined from the radiological records. During the second stage, the information regarding the type of vehicles involved in the accidents and the

position of the injured person in the vehicle was investigated from the motor vehicle accident records in the judicial investigation files. The information regarding these subjects was obtained from the accident victim or their legal representatives by face-to-face interviews to confirm the information obtained from the judicial investigation files or to access information that could not be obtained in the judicial investigation files.

In the classification of the vehicle type, we categorized the type of vehicle as small vehicles (e.g., automobile, jeep, and minivan including a 5–7-person capacity) and larger passenger vehicles (e.g., minibus and bus). In this study, motorcycle, truck, and agricultural vehicle accidents were not included into the data pool because they contain more diverse and complex injury mechanisms. Additionally, side and rear collisions and overturns were not included in the scope of this study for the same reasons.

In the classification of the position of the injured persons in the vehicles, we categorized the type of person as driver, front seat passenger, or rear occupant. In this study, passengers sitting in the rear seats of large passenger vehicles were evaluated as the rear occupants.

In the classification of the fractured bone location, fractures were classified as “pelvic fractures”, “upper leg fractures” (hip, femur, and patella fractures) and “lower leg fractures” (tibia, fibula, ankle, and foot fractures). Although, the inclusion of the patella as part of the upper leg and the inclusion of the foot as part of the lower leg is outside of conventional approaches, we chose this path because of the difficulty of classification due to the small number of patella and foot fractures and the scarcity of the total number of cases.

In this study, SS was calculated according to TFSS arranged for Turkish forensic medicine application of the Turkish Penal Code [7]. Part of the TFSS concerning pelvic and lower limb fractures used in Turkish forensic medicine application is shown in Table 1. According to TFSS, the SS was calculated as follows:

For only 1 fracture, the score is in the TFSS.

For more than 1 fracture,

$$SS^* = \sqrt{1^{st} \text{ fracture score}^2 + 2^{nd} \text{ fracture score}^2 + 3^{rd} \text{ fracture score}^2 + \dots}$$

(\*). Obtained number rounded up to the nearest whole number. Maximum is 6.

The resulting data were statistically assessed by a chi-square test *t* test, and a one-way ANOVA using IBM SPSS version 20. The statistical significance levels were set at 5%.

For this study, ethics approval was obtained from the Ethics Board of the Medical School of Yuzuncu Yil University (28.01.2015, B.30.2.YYU.0.01.00.00/18).

## Results

In this study, 191 patients who were injured in frontal collision vehicular accidents were evaluated. In total, 71.2% of the patients were males and 28.8% were females. For males, the mean age was  $32.4 \pm 10.4$  (min: 5, max: 52) years, and for females it was  $35.2 \pm 15.5$  (min: 4, max: 74) years ( $p=.135$ ). Most of the patients (55.5%) were in the 19–36 years age group. Most patients (86.4%) were injured in small vehicles and 13.6% were injured in large passenger vehicles. The mean number of persons in the vehicle during the accident was  $3.5 \pm 1.3$  (min: 1, max: 7) in small vehicles and  $17.3 \pm 15.2$  (min: 1, max: 45) in large passenger vehicles ( $p=.000$ ). Fifteen of the accidents involved only 1 person. Approximately half of the patients (49.2%) were rear occupants, followed by front seat passengers (27.8%) and drivers (23%) (Table 2).

In total, 293 fractures occurred in 231 body region of 191 patients. Upper leg fractures were the most commonly seen type of fractures in patients (31.9%). When multiple fractures occurred in 3 regions, the rate of upper leg fractures reached 37.7% ( $n=87$ ), followed by upper leg fractures ( $n=74$ ; 32.0%) and pelvic fractures ( $n=70$ ; 30.3%) ( $p=.358$ ). We found no statistically significant differences between location of fractures, and sex, age groups, and vehicle types. However upper leg fractures were more common in drivers whereas pelvic fractures were more common in front seat and rear seat passengers.

There were pelvis and lower limb fractures on the left side of the body in 46.6% of patients, fractures on the right side of the body in 23.0% of patients, and bilateral fractures in 30.4% of patients. Left side dominance was not statistically significant when it correlated with sex, age groups, and position in the vehicle. However, the rate of fractures of the left side were significantly higher in both types of vehicles. There were 152 patients (79.6%) who had fractures in only one body region (either the pelvis, upper leg, or lower leg), whereas there were fractures at multiple regions in 39 patients (20.4%) ( $p=.000$ ). The mean SS of all patients was  $2.57 \pm 1.56$ . There was a statistically significant difference between mean SS and sex ( $p=.005$ ). However, we found no statistically significant difference between mean SS, and age groups, vehicle types, and position in vehicle (Table 2).

The majority of pelvis fractures and multiple fractures including pelvis fractures were bilateral, whereas most upper leg and lower leg fractures was on the left side ( $p=.000$ ) (Table 3). None of the patients in the present series died. The SS was  $2.78 \pm 1.44$  in bilateral fractures,  $2.66 \pm 1.71$  in left-side fractures,

and  $2.09 \pm 1.31$  in right-side fractures ( $p=.064$ ). SS was  $4.50 \pm 1.77$  in pelvis + upper leg fractures,  $3.29 \pm 1.57$  in upper leg + lower leg fractures, 3.00 in pelvis + upper leg + lower leg fractures,  $2.69 \pm 1.55$  in pelvis + lower leg fractures,  $2.60 \pm 1.69$  in lower leg fractures,  $2.46 \pm 1.60$  in upper leg fractures, and  $2.09 \pm 1.31$  in pelvic fractures ( $p=.001$ ).

## Discussion

In people who died or were injured in motor vehicle accidents, the determination of the localization and severity of the traumatic lesions is very for forensic analysis [3]. The most frequently injured body region was the lower limb in non-fatal hospitalized patients or non-hospitalized patients with minor trauma in motor vehicle accidents [8]. Lower-extremity injuries are “a common and costly cause of permanent disability and impairment resulting from motor vehicle crashes” [9]. Additionally, pelvic fractures were common in motor vehicle accidents and were a significant source of morbidity and mortality [10].

In previous studies, male dominance among persons injured in motor vehicle accidents was reported as 58% in Great Britain [11], 71.9% in China [12], 76% in France [13], 74.4% in India [14], and 94.1% in Pakistan [15]. In a study from the United States, females reportedly had higher non-fatal injury rates as passenger vehicle occupants, and males had significantly higher fatality rates than females [16]. Other studies reported that “males are more severely injured in all body regions because they take more risks” [13,17]. In the present study, 71.2% of injured patients were males, and the mean SS was significantly higher in males ( $p=.005$ ).

Most of the patients were in the 19–36 years age group ( $n=106$ ; 55.5%;  $p=.000$ ). This finding is consistent with that reported in the literature [13–16]. Bina et al. emphasized that due to risky driving, injuries and deaths in motor vehicle accidents were the highest in adolescents [18]. In the present study, the mean SS reached the highest score ( $SS=2.83$ ) in the 19–36 years age group ( $p=.072$ ). Several studies reported that fatality rates due to motor vehicle crashes peaked in adolescents and the elderly. The reason for the increasing fatality rates in elderly people was explained by their physical vulnerability [13,16]. However, there were no fatal cases in this study, perhaps because we did not include patients with concomitant injuries.

In this study, 86.4% of patients were injured in small vehicle motor vehicle accidents, whereas 13.6% were injured in large passenger vehicles ( $p=.000$ ). The number of small vehicles is approximately 14 times that of large passenger vehicles in Turkey, and according to the data from TURKSTAT, the injury rate in small vehicles was approximately 2 times that in large

**Table 1.** Part of the Turkish Fracture Severity Scale (TFSS) concerning pelvic and lower limb fractures used in Turkish forensic medicine.

Types of fractures	SS	Types of fractures	SS	Types of fractures	SS
Small avulsion fractures of the iliac bone	1	Open fractures of the femoral neck	5	Open Pilon-tibial fractures	5
Corpus fractures of the iliac bone	2	Intertrochanteric fractures	4	Closed malleoli fractures	2
Dissociated corpus fractures of the iliac bone	3	Open intertrochanteric fracture	5	Open malleoli fractures	3
Iliac wing fractures (Duvarney fracture)	2	Subtrochanteric fractures	4	Bimalleolar closed fractures (Pott's fractures)	3
Open fractures of the iliac crest	2	Open subtrochanteric fractures	5	Bimalleolar open fractures	4
Unilateral ischial fractures	2	Femoral condyle (medial/lateral) fractures	4	Trimalleolar fractures (Cotton's fractures)	3
Bilateral ischial fractures	3	Femoral epicondyle fractures	2	Open Cotton fractures	4
Unilateral fractures of the superior ramus pubis	2	Supracondylar femur fractures	4	Fractures of the calcaneus	2
Bilateral fractures of the superior ramus pubis	3	Open supracondylar fractures of femur	5	Fragmented and/or open fractures of the calcaneus	3
Joint fractures of the ischium and the superior ramus pubis	3	A perforated femur fractures (firearms)	3	Fractures of the talus	2
Separations of the symphysis pubis (less than 3 cm)	3	Small avulsion fractures of the patella (partial)	1	Fragmented and/or open fractures of the talus	3
Separations of the symphysis pubis (more than 3 cm)	4	Open partial fractures of the patella	3	Tarsal bone fractures	2
Acetabular fractures (ceiling/upper lip)	3	Patella fractures	2	Radiocarpal, pericarpal, intercarpal, subtalar fractures	3
Dissociated acetabular fractures of the base	4	Fragmented patella fractures	3	Open fractures of the tarsal bones	3
Acetabular fractures and dislocations of the femur head	5	Open fragmented patella fractures	4	Sesamoid fractures	1
Sacroiliac separations (if fractures are unilateral)	3	Knee dislocations	3	Metatarsal fractures	2
Sacroiliac separations (if fractures are bilateral)	4	Small avulsion fractures of the tibia	1	Open metatarsal fractures	3
Malgaigne fractures (unilateral)	4	Tibial shaft fractures	4	Metatarsal dislocations	3
Malgaigne fractures (bilateral)	6	Open tibial diaphyseal fractures	5	Femoral shaft fractures	4
Fractures of the sacrum	3	Tibial plateau (lateral-medial condyle) fractures	3	Fragmented femoral shaft fractures	5
Fragmented fractures of the sacrum	4	Fragmented tibial plateau (lateral-medial condyle) fractures	4	Open femoral shaft fractures	5
Coccyx fractures	2	Fractures of the tibial plateau and the fibula head	4	Open and fragmented femoral shaft fractures	6
Dislocations of the femoral head	4	Fibular shaft fractures	2	Toe bone fracture	2
Nondisplaced fractures of the femoral head	4	Open fibular shaft fractures	3	Open fractures, amputation of toe bone fractures	1
Displaced fractures of the femoral head	5	Fibular neck fractures and condylar fractures	3	Toe bone fracture	2
Femoral neck (collum) fractures	4	Pilon-tibial fractures	4	Toe bone dislocation	1

Table 2. Patient characteristics and fracture features.

Features of person	Total	Sex		Age groups				Type of vehicles		Position in vehicle of persons		
		Male	Female	0-18	19-36	37-54	55-74	Small vehicles	Larger pass-anger vehicles	Driver	Front seat pass-engers	Rear seat pass-engers
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Cases	191 (100)	136 (71.2)	55 (28.8)	14 (7.3)	106 (55.5)	64 (33.5)	7 (3.7)	165 (86.4)	26 (13.6)	44 (49.2)	53 (27.7)	
P values		.000		.000				.000		.000		
Body side of fractures												
Right	44 (23.0)	32 (16.8)	12 (6.3)	4 (2.1)	28 (14.7)	11 (5.8)	1 (0.5)	40 (20.9)	4 (2.1)	11 (5.8)	10 (5.2)	
Left	89 (46.6)	65 (34.0)	24 (12.6)	7 (3.7)	50 (26.2)	31 (16.2)	1 (0.5)	71 (37.2)	18 (9.4)	22 (11.5)	21 (11.0)	
Bilateral	58 (30.4)	39 (20.4)	19 (9.9)	3 (1.6)	28 (14.7)	22 (11.5)	5 (2.6)	54 (28.3)	4 (2.1)	11 (5.8)	22 (11.5)	
P values	.000	.726		.192				.043		.360		
Location of fractures												
Pelvis	48 (25.1)	30 (15.7)	18 (9.4)	0 (0.0)	21 (11.0)	23 (12.0)	4 (2.1)	44 (23.0)	4 (2.1)	0 (0.0)	17 (8.9)	
Upper leg	61 (31.9)	44 (23.0)	17 (8.9)	5 (2.6)	35 (18.3)	19 (9.9)	2 (1.0)	51 (26.7)	10 (5.2)	18 (9.4)	16 (8.4)	
Lower leg	43 (22.5)	33 (17.3)	10 (5.2)	5 (2.6)	26 (13.6)	12 (6.3)	0 (0.0)	35 (18.3)	8 (4.2)	11 (5.8)	10 (5.2)	
Pelvis + upper leg	8 (4.2)	6 (3.1)	2 (1.0)	1 (0.5)	6 (3.1)	0 (0.0)	1 (0.5)	8 (4.2)	0 (0.0)	1 (0.5)	3 (1.6)	
Pelvis + lower leg	13 (6.8)	8 (4.2)	5 (2.6)	0 (0.0)	7 (3.7)	6 (3.1)	0 (0.0)	11 (5.8)	2 (1.0)	5 (2.6)	4 (2.1)	
Upper leg + lower leg	17 (8.9)	14 (7.3)	3 (1.6)	3 (1.6)	11 (5.8)	3 (1.6)	0 (0.0)	15 (7.9)	2 (1.0)	8 (4.2)	3 (1.6)	
Pelvis + upper leg + lower leg	1 (0.5)	1 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.5)	0 (0.0)	1 (0.5)	0 (0.0)	1 (0.5)	0 (0.0)	
P Values	.000	.606		.063				.683		.005		
Ss												
Mean of Ss	(2.57)	(2.76)	(2.07)	(2.36)	(2.83)	(2.22)	(2.14)	(2.58)	(2.46)	(2.98)	(2.45)	
Standart deviation of Ss	(1.56)	(1.68)	(1.09)	(1.39)	(1.71)	(1.33)	(0.69)	(1.55)	(1.63)	(1.71)	(1.50)	
P Values	.000	.005		.072				.716		.136		

passenger vehicles in Turkey [19]. Small vehicles, were most common in the present study, and we found no statistically significant difference between mean SS and vehicle type ( $p=.716$ ).

Lee and Abdel-Aty reported that drivers generally displayed safer driving behavior when passengers accompany drivers due to the increased responsibility of carrying more passengers



**Table 3.** Correlation between body side and location of fractures.

Location of fractures	Body side of fractures				P values
	Right	Left	Bilateral	Total	
	n (%)	n (%)	n (%)	n (%)	
Pelvis	9 (4.7)	7 (3.7)	32 (16.8)	48 (25.1)	.000
Upper leg	16 (8.4)	42 (22.0)	3 (1.6)	61 (31.9)	
Lower leg	13 (6.8)	28 (14.7)	2 (1.0)	43 (22.5)	
Pelvis + upper leg	0 (0.0)	2 (1.0)	6 (3.1)	8 (4.2)	
Pelvis + lower leg	2 (1.0)	2 (1.0)	9 (4.7)	13 (6.8)	
Upper leg + lower leg	4 (2.1)	8 (4.2)	5 (2.6)	17 (8.9)	
Pelvis + upper leg + lower leg	0 (0.0)	0 (0.0)	1 (0.5)	1 (0.5)	
Total	44 (23.0)	89 (46.6)	58 (30.4)	191 (100)	

and the consequent safer driving behavior [20]. In contrast, Ulleberg reported that the accident risk of young drivers rises when the number of passengers increases [21]. In the present study, the high number of passengers (sometimes exceeding the vehicle's capacity) in the vehicles during accidents is considered to be one of the factors that caused the accidents.

The risk of death and severe injury has been reported to be 2 times higher in drivers and front-seat passengers in frontal and lateral collisions [22]. A high risk of injury and death of drivers and front-seat passengers was also confirmed in several studies [23]. In the present study, almost half of the patients (n=94; 49.2%) were rear occupants, followed by front seat passengers (n=53; 27.8%) and drivers (n=44; 23%); however, the mean SS was the highest (SS=2.98) in drivers (p=.136).

Massie et al. reported that male drivers (3.5 fatal involvements per 100 million miles) had a higher mortality risk than female drivers (2.2 fatal involvements per 100 million miles), although the incidence of injury to female drivers (2.3 injury involvements per million miles) was more than that of male drivers (1.8 injury involvements per million miles) in traffic accidents [24]. In the present study, only 2 (4.5%) of 44 drivers were females. This finding is associated with the low rate of female drivers in Turkey, especially in East Anatolia, due to cultural factors.

In the present study, SS of multiple region fractures was significantly higher than single-region fractures, as expected (p=.000). Upper leg fractures were the most common type (p=.358), consistent with the literature [9,10,25].

The lateralization of injuries inflicted by traffic accidents is very rare in the literature. Fildes et al. reported that left foot

fractures are more frequent, especially in drivers, due to associations with the pressure of the pedal [25]. In India (left-hand traffic), 50.0% of lower limb fractures and 54.9% of lower limb and pelvis fractures were located on the right side of the body [14]. In contrast, most pelvis fractures and multiple fractures including pelvis fractures were bilateral, whereas most upper leg and lower leg fractures was on the left side in this study (p=.000). Additionally, SSs of patients were 2.78±1.44 in bilateral fractures, 2.66±1.71 in left-side fractures and 2.09±1.31 in right-side fractures (p=.064).

It was reported that there was a correlation between impact speed/property damage and injury risk or severity [26,27]. In the present study, impact speed and property damage could not be evaluated due to the lack of documentation.

## Conclusions

In the literature, data on the type of lower limb and pelvic fractures occurring during motor vehicle accidents are limited. This study revealed that most lower limb and pelvic fractures occurred in males, in people 19–36 years old, and in small vehicles and rear seat passengers. Fractures occurring in left side of the body and upper legs were the most common. Fractures of males were more serious than those of females. Defining the mechanism of injury, the placement of the body, the severity degree, and other characteristics of fractures is very important for the automobile industry to prevent damage that occurs during crashes. Additionally, these data are important for forensics and criminal scientists to determine the position of dead or injured patients within a vehicle. These results will also be a resource for trauma studies.

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