original article

Escalator-related injuries in one of the deepest subway stations in Europe

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BACKGROUND: Escalator-related injuries (ERI) have emerged as a new injury type due to the frequent use of escalators in Metro stations.
OBJECTIVES: Investigate ERI in the stations on the Marmaray metro line.
DESIGN: Retrospective, observational study.
SETTING: Patients admitted to the emergency department of a training and research hospital.
PATIENTS AND METHODS: All patients with ERI were included in the study. We analyzed demographic characteristics, injury type and anatomical location of injury, Glasgow coma score, and body mass index (BMI). Patients were grouped by BMI: underweight (BMI<18.5 kg/m^2), normal weight (BMI=18.5–24.9 kg/m^2), overweight (BMI=25–29.9 kg/m^2) and obese (BMI≥30kg/m^2).
MAIN OUTCOME MEASURES: Injury characteristics and BMI values of patients with ERI.
SAMPLE SIZE: 82 patients.
RESULTS: The mean age was 45.1 (15.5) years (range:14–77 years). Forty-two were women (52.5%). The mean BMI was 26.7 (2.2) kg/m^2 (range: 22.1–33.3 kg/m^2)]. Most of the patients who were injured due to escalators were older than 50 years (n=39, 47.6%) and 77.5% (n=62) of all patients were overweight. There was a significant relationship between increased BMI and serious ERI (*P*=.010, OR: 1.85, 95% C.I: 1.13-2.65). The most frequent mechanism of injuries was a fall (97.6%). The majority of injuries were the head (42%) and extremity injuries (33%). The major type of ERI was soft tissue injuries (41.3%), followed by lacerations (20.7%), closed head injuries (18.5%), fractures (15.2%) and serious injuries (4.4%). Serious injuries were more prevalent in patients aged older than 50 years (*P*<.05), and in overweight and obese individuals (*P*<.001)
CONCLUSION: Novel protective measures against ERI should be developed for crowded subway stations.
LIMITATIONS: The small sample size and retrospective nature.
CONFLICT OF INTEREST: None.

Metro systems are preferred in many cities because they are fast and comfortable. Passengers must enter or leave a metro station via stairs, escalators, or elevators and are at risk of unintentional injury.[1-4] Most of the accidental injuries in metro stations are associated with escalators.[4] Injuries on escalators can cause traumatic deaths. The number of escalator injuries is 20 times higher than elevator injuries.[2]

Because of the combination of crowding and high escalator speed, escalator-related injuries (ERI) have emerged as a new way of injury. At 65 meters long, the escalators in the Vezneciler Metro Subway station are among the longest in Europe: the trip on the escalator takes 1.5 minutes. Therefore, the escalators in the Marmaray line pose the same potential risk as other major metro stations.[3]

There have been a few studies of injuries occurring on metro escalators. However, demographic and clinical characteristics of this trauma type have not been adequately investigated. This study presents the demographic and clinical features of all injuries that occurred in association with escalator use on the the Marmaray metro line and evaluates the relationship between body mass index (BMI) and ERI.

PATIENTS AND METHODS

This retrospective, cross-sectional observational study of ERIs occurring on the Marmaray subway stations that were treated in a large emergency care hospital in Istanbul between January 2015 and December 2015. The Marmaray Subway, which was completed in 2015, is the world's first intercontinental subway system. The line of Marmaray subway includes a 13.7-km rail tunnel that runs almost 200 feet below the Bosporus seabed and was designed to ease congestion in Istanbul. It is a 76-km-long subway line running from Halkali (in Europe) to Gebze (in Asia), comprising both upgraded and new parts.[3] The Marmaray Sirkeci-Cağaloğlu station is located 60 meters underground. ERIs were identified by reviewing the medical records of all patients treated in the emergency department of Haydarpasa Numune Training and Research Hospital, University of Health Sciences, Istanbul, Turkey. This hospital serves as a state-designated regional trauma center and is the primary receiving hospital for the region. The hospital treats large volumes of patients not considered to have severe injuries, as well as those identified as requiring treatment at a trauma center.

Data collected for analysis included age, weight and height, date, type and anatomical location of the injury, the mechanism, details of the traumatic injury, Glasgow Coma Scale (GCS) score, and admission time (arrival time to the emergency department from the scene). The inclusion criterion was an injury sustained due to the use of an escalator on the Marmaray line. The exclusion criteria were having an injury unrelated to escalator use, having a non-traumatic injury and having incomplete demographic data. The examiners identified all patients who met the study inclusion/exclusion criteria and documented the anatomical and physiological details of the injury. The injuries according to anatomical site were divided into five categories for analysis: head (head, face, eye, ear, and mouth), extremity (shoulder, upper arm, elbow, forearm, wrist, hand, fingers, leg, knee, ankle, foot, and toes), spine (cervical, thoracic and lumbar vertebrae), thoracic region (thorax, rib, and scapula) and abdominal region (abdomen, hip and sacrum). The types of injuries were grouped into five categories: Soft tissue injury (abrasion, contusions, crush, sprain, and strain), fracture/dislocation, laceration (avulsion, laceration, hemorrhage, and hematoma), closed head injury, serious injuries (subdural hematoma, vertebral compression fracture with neurologic deficit).

The BMI was calculated as person's weight in kilograms divided by the square of the person's height in meters (kg/m^2). Patients were clustered into four groups according to BMI classification of the World Health Organization; underweight: BMI<18.5 kg/m^2, normal weight: BMI=18.5–24.9 kg/m^2, overweight: BMI=25–29.9 kg/m^2 and obese: BMI≥30 kg/m^2. Patients were divided into four age groups for data analysis.

Data were analyzed with SPSS for Windows software (version 17.0; IBM Corp., Armonk, NY, USA). Normal distribution was tested by using a Kolmogorov Smirnov normality test. The quantitative data were expressed as mean and standard deviation, or median and minimum-maximum, where applicable. Categorical data were compared using the chi-square test and were expressed as number and percentage. Data were analyzed with the Mann Whitney U test for comparisons between ERI and demographic characteristics and by multivariate logistic regression to assess the relationship between serious ERI and BMI, age and gender. The *P* value of <.05 was considered as significant statistically.

RESULTS

The 82 injured individuals were mostly aged over 50 years (n=39, 47.6%) (**Table 1**). The most common mechanism of all the injuries was the fall (n=80, 97.6%). The remaining injuries were due to entrapment of an extremity (n=2, 2.4%). The most common injuries were head (n=34, 42%) and extremity injuries (n=27, 33%). The major types of ERI are shown in **Table 2**. No patient died due to ERI. The majority of serious injuries, fractures, and closed head injuries occurred in patients aged older than 50 years (for each, *P*<.05). Soft tissue injuries were most prevalent in the patients aged 19–40 years. There was no statistically significant relationship between the type of injury and gender (*P*=.782)

A high BMI value was the primary risk factor for serious ERI (*P*=.010, OR: 1.85, 95% C.I: 1.13-2.65) (**Table 3**). The multiple logistic regression analyzes the factors related to trauma in patients with and without serious escalator injuries (4 patients with subdural hematoma and vertebral compression fracture and 2 patients with multiple trauma). In normal-weight patients, soft tissue injuries were more common, whereas in overweight and obese patients, serious injuries and closed head injuries were more common (*P*< .020) (**Figure 1**).

Table 1. Demographic and clinical characteristics of patients injured on escalators in the Metro stations (n=82).

Parameters	
Females	42 (51.2)
Age (years)	45.1 (15.5)
Age groups (years)	
≤18	8 (9.8)
19-40	20 (24.4)
41-50	15 (18.3)
>50	39 (47.6)
Height (meters)	1.65 (0.09)
Weight (kg)	74.3 (10.5)
Body mass index (kg/m^2)	26.7 (2.2)
Admission time (min)	112 (53.8)
Glascow Coma Score	14.9 (0.15)
Anatomical site, n (%)	
Head injury	34 (42)
Extremity injury	27 (33)
Spine injury	9 (11)
Thoracic injury	8 (10)
Abdominal injury	4 (5)

Data are mean (standard deviation) or number (percentage).

Fifty-two percent of the patients were treated in the emergency department. Other departments that treated injuries were orthopedic surgery (25%), neurosurgery (12.5%), thoracic surgery (7.5%), and general surgery (2.5%) departments.

DISCUSSION

To our knowledge, this is the first study to evaluate injuries occurring on long escalators in Europe and analyze injuries by BMI. Escalator accidents are common in all age groups. However, previous studies have reported varying accident rates by age groups in different countries for injuries due to escalators. In several studies, children have been reported to be a particularly vulnerable population.[5-7] Children may remain standing on the escalator and try to 'slip off', instead of stepping off. This can result in entrapment of the feet within the gap where the last plate slides into the comb plate.[7] In the United States, McGeehan et al found that children who were younger than 5 years had the highest estimated number of injuries.[5] Platt et al reported that escalator injuries were most common in children aged 2-4 years.[6] In contrast, in a recent study conducted in China, elderly passengers accounted for the highest proportion of all ERIs (49.1%).[1] In Taiwan, Chi et al reported that 50.5% were sustained by people over 65 years of age.[8] In our study, the majority of the injured individuals were over 50 years old. ERI is more frequent in the elderly than in children due to difficulty stepping on or off the escalator and the slowing of their steps.

Table 2. Distribution of type of injury by age group and gender.

Type of injury	Total (n=92)[a]	Gender		Age group			
		Male	Female	≤19	19-40	41-50	>50
Soft tissue injury	38 (41.3)	20 (52.6)	18 (47.4)	4 (10.5)	11 (28.9)	10 (26.3)	13 (34.2)
Laceration	19 (20.7)	9 (47.4)	10 (52.6)	2 (10.5)	4 (21.1)	4 (21.1)	9 (47.4)
Closed head injury	17 (18.5)	10 (58.9)	7 (41.2)	0	2 (11.8)	2 (11.8)	13 (76.5)
Fracture	14 (15.2)	8 (57.1)	6 (42.9)	2 (14.3)	4 (28.6)	2 (14.3)	6 (42.9)
Serious injuries[b]	4 (4.4)	1 (25)	3 (75)	0	0	0	4 (100)

Data are number (percentage). [a]92 injury types due to patients having two injury types, [b]Serious injuries: subdural hematoma, vertebral compression fracture.

Table 3. Multivariate logistic regression analysis for factors related ERI.

Variables	Beta	S.E.	Wald	*P* value	OR	95% C.I.	
BMI	.615	.244	6.329	**.012**	1.849	1.145	2.985
Age	-.009	.045	.037	.848	.991	.907	1.083
Gender	1.151	1.084	1.126	.289	3.160	.377	26.464

Model summary: -2 log likelihood =32.896, Cox & Snell R square=.114, Nagelkerke R square=.277, Omnibus test of model: chi-square=9.726, df=3, *P*=.021.

In Istanbul, traffic makes many people late for work, and although the Marmaray metro line provides a faster travel option, the rush to arrive on time has a greater effect on older individuals using the station. We also found that the most common mechanism of escalator injuries was the fall (97.6%) and gender distribution was almost 1:1.

One study reported that the most frequently injured body parts were the lower extremities (25.9%) and the head (25%).[2] Another study found that the most common injuries occurred in multiple body regions (27.2%) and the head and neck (21.5%).[1] In our study, the most prevalent escalator injuries were head and extremity trauma. The most frequent causes of head trauma are car and occupational accidents, falls from a height, gunshot injuries, and blows.[9-11] However, injuries associated with escalators may lead to head trauma. Probably, these injuries are among common causes of head trauma. The type of ERI has been documented in a few studies in the literature. A recent study categorized escalator injuries into five subtypes for the purposes of risk management: soft tissue injuries, fractures, lacerations, closed head injuries, and others (i.e., injuries resulting in burns, cardiac arrest, or complete body trauma) and the leading type of injury was soft tissue injuries (54.2%) followed by lacerations (22.3%) and fractures (15.6%).[2] Howland et al found that 43% of escalator falls resulted in soft tissue injury, followed by 34% lacerations, 3% fracture/dislocations, <2% closed head injury, and 8% no documented injury.[12] We found that most injuries were soft tissue injuries and lacerations, but some patients suffered from severe injuries.

Although the association of BMI with various illnesses has been studied, studies investigating BMI on trauma patients are scarce, and have conflicting results. Some studies demonstrated that there is a significant association between BMI and an increased risk of injury, whereas one study suggested that increased BMI is not a risk factor for trauma patients.[13-15] To the best of our knowledge, there is no study on the effect of BMI in the occurrence of ERI. According to Statistical Institute data in Turkey, 17.2% of the population aged 15 years or older are obese, 34.8% are overweight, 44.2% are normal weight, and 3.9% are underweight. According to these data, 52% of our population is overweight.[16] We showed that 77.5% of ERI were in overweight individuals, a higher rate than their representation within the general population. A high BMI value was associated with an increased risk for this injury. Some studies reported an increased rate of extremity trauma in overweight individuals suffering from motor accidents.[15,17] In contrast to previous reports, a study conducted by Durgun et al observed that the rate of head trauma and serious injuries was higher in patients with increased BMI than normal weight.[16] In our study, injuries related to the escalator in overweight and obese patients more often caused serious injuries and closed head trauma. Escalators are a moving platform with relatively high speed. We think that movement and balance deterioration due to

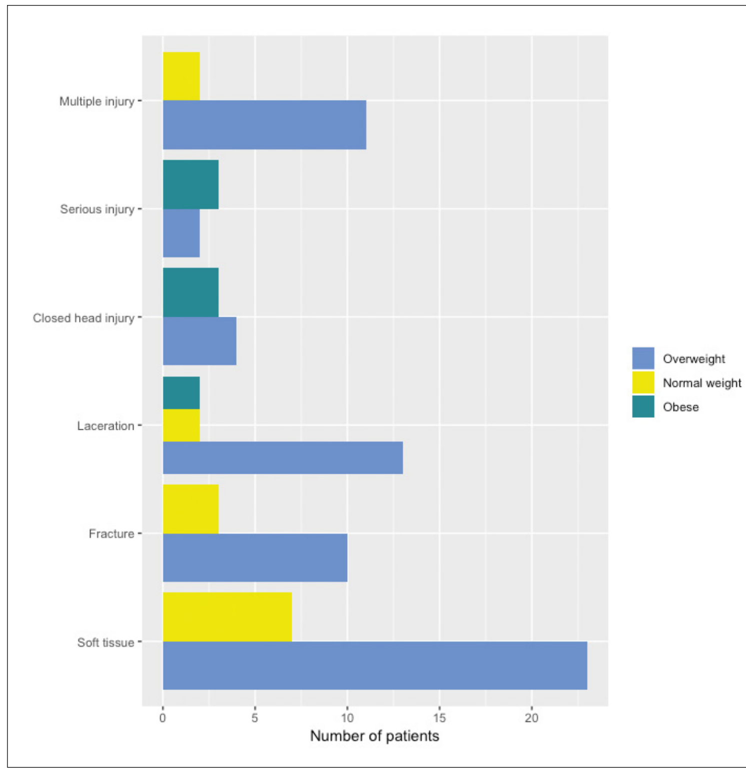

Figure 1. Distribution of injury types by body mass index.

the excessive weight of the person may cause a higher risk of escalator-related accidents and serious injuries in these individuals compared to normal weight individuals.

Studies that evaluate the distribution of injured body regions according to age groups are limited for ERI. One study showed that the proportion of head injuries and the proportion of lower extremity injuries increased with increasing age, and severe injuries were greatest in old age groups.[2] We also found that elderly adults experienced more frequent extremity and closed head traumas and more serious trauma. This may be related to difficulty in balanced walking and a decrease in agility in elderly persons. Additionally, the combination of crowding and the high speed could increase the incidence of serious injuries in the elderly.

The metro system provides people with a fast travel option. Crowded subway escalators carry large numbers of people from one level to another.[8,12] Strategies to protect vulnerable people and improve equipment and infrastructure may reduce the incidence of injuries.[1,2] Although metro systems have high-quality escalators designed to prevent injuries,[3] our study showed that even serious injuries can occur, such as subdural hematoma and vertebral compression fracture with neurological deficit. Therefore, protective measures should be developed to prevent injuries on crowded escalators in subway stations. Novel protective measures against ERI should be developed for crowded subway stations, taking into account the demographic and clinical characteristics of these injuries. For example, we found that most of the injuries occurred in elderly and overweight individuals due to falls, and serious injuries were seen in these people. Therefore, elderly and overweight and/or obese individuals may be routed to elevators directly to prevent injuries. In addition, providing short, multiple and large escalators may reduce ERI in overcrowded stations.

This study has several limitations. First, the small sample size and retrospective nature of the study may limit the generalizability of conclusions. Nevertheless, this is one of the largest single series of injuries occurring on one of the longest escalators in the world reported to date. Second, medical factors for patient with diabetes, such as eye problems could not be investigated. Third, the weight and height values of some patients who could not be measured due to their injury characteristics such as immobility were recorded according to the patient's declaration. Finally, some cases may have been missed, where the minor injuries may have been triaged to other institutions or may not have resulted in any medical evaluation whatsoever. Because the number of people who were injured is relatively small in this study, there is a need for more comprehensive and prospective studies for enough information about prevention.

In conclusion, this study showed that most ERI occur in elderly patients and the most common etiology was the fall. We also found that soft tissue injuries were most common. Severe injuries and closed head injuries were more frequent in elderly patients than in younger patients. Major risk factors were increased BMI and we suspect that age would be significant in a larger sample. Therefore, alternative systems for elderly and obese individuals should be designated to reduce the incidence of ERI.

The study was conducted in accordance with the principles of the Declaration of Helsinki and STROBE guidelines.

Author contributions

A.A., M.O.E., I.T., and K.Y. participated in the design of the study; A.A., M.O.E, I.T., and K.Y. in data collection; A.A., U.G., M.O.E I.T., K.Y. and U.L. in the literature search; and A.A., U.G., and U.L. in writing of the manuscript; and in revising it critically for important intellectual content U.G., U.L.

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