Wien Klin Wochenschr (2015) 127:57–61
DOI 10.1007/s00508-014-0639-9

Wiener klinische Wochenschrift
The Central European Journal of Medicine

Injury pattern in correlation with the height of fatal falls

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Received: 17 February 2014 / Accepted: 7 October 2014 / Published online: 20 November 2014

Summary
Background Death due to blunt trauma as a sequel of falls, as a cause of an increased life span is expected. The aim of this retrospective study was to examine the correlation between the height of fall and the frequency, the extensiveness, and the type of injuries of certain body regions and organs.

Methods The study included 201 cases of fatal falls, which consisted 118 male and 83 female cases. All subjects were assessed in a standard autopsy for height of fall, cause of death, and injury pattern.

Results Concerning the height of fall, 111 (55.2%) cases involved falls on a plane level, 72 (35.8%) from one level to another lower level, less than 5 meters, and 18 (9%) cases from one level to another lower level, more than 5 meters. Mean age at the time of death was 66.7-years-old (range 22–98). The immediate cause of death was in 94 cases blunt head trauma, in 40 cases cardiovascular diseases, in 56 cases bronchopulmonal diseases, in 3 patients Polytrauma, in 5 patients multi organ failure, and in 3 patients other causes were identified. At the autopsy, 66 patients showed fractures of the skeletal system. The most common cause of death independent from the height of fall was head trauma with 46.7%.

Conclusion Both post-mortem findings and medical and psychiatric history, in conjunction with the findings at the death scene and toxicology results have to be considered to obtain the clearest possible picture of the circumstance of death.

Keywords Injury pattern · Height of fall · Cause of death · Head trauma · Fatal falls

Tödliche Stürze – Verletzungsmuster in Abhängigkeit von der Sturzhöhe

Zusammenfassung
Grundlagen Stürze werden aus rechtsmedizinischer Sicht als eine von hoher kinetischer Energie getragenen Abwärtsbewegung des Körpers mit abruptem Auftreffen auf den Boden definiert. Da die Fallhöhe die Aufprallgeschwindigkeit und damit die kinetische Energie des Aufpralls bestimmt, stellt sie den entscheidensten Parameter für das Verletzungsbild und die Letalität dar.

Ziel dieser retrospektiven Studie war es, Stürze zu ebener Erde von Stürzen von einer Ebene auf eine andere (Sturzart) zu differenzieren und die daraus resultierenden Verletzungsmuster zu analysieren.

Methodik In einem Zeitraum von 2 Jahren wurden im Institut für Rechtsmedizin München 4867 Obduktionen durchgeführt, davon gingen über 4% der Fälle auf Sturzereignisse zurück. Diese wurden mittels der Sektionsprotokolle, Krankengeschichten und katamnestischer Angaben nach folgenden Kriterien ausgewertet: Alter, Geschlecht, Todesursache, -umstände, Sturzart, äußere und innere Verletzungen sowie Überlebenszeit.

Ergebnisse Unter den 201 obduzierten Gestürzten fanden sich 118 Männer und 83 Frauen. Das Durchschnittsalter betrug 66,7 Jahre (22–98 Jahre), wobei 60,7% der tödlichen Sturzereignisse auf > 65jährige fielen. 111 der Betroffenen stürzten zu ebener Erde, bei 72

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war die Sturzhöhe gering und 18 kamen bei einem Sturz aus großer Höhe ums Leben.

Die häufigste Todesursache, unabhängig von der Sturzhöhe, war das stumpfe Schädel-Hirn Trauma (46,7 %).

Schlussfolgerung Im Rahmen der durchgeführten Obduktionen konnte bei den Gestürzten als häufigste Todesursache – unabhängig von der Sturzhöhe – ein Schädel-Hirntrauma festgestellt werden.

Schlüsselwörter Verletzungsmuster · Sturzhöhe · Todesursache · Schädel-Hirn Trauma · Tötliche Stürze

Introduction

Deaths due to blunt trauma as a sequel of falls are a common phenomenon especially occurring in urban settings [1]. In particular cases, the mode of death is unclear at the time the body is found, and the presence of multiple blunt force injuries makes it hard to differentiate between fall-induced injuries and those that have inflicted before the fall. Falls are defined as falling from one level to another level or on the same level [2]. Falls from a height refer to falls from one higher level to another lower level [2]. Falls from a height occur generally in accidents or suicides, and occasionally as an act of homicide. The height of fall is a major determining factor of injury because at the moment of impact, a falling body undergoes deceleration and the amount of kinetic energy transferred to the ground reacts with an equal amount of energy against the body [3]. Injuries result from the absorption of the lost energy [3].

Numerous studies exist that explain the mechanism of injury in falls from various heights [2–5]. However, there are few studies in the available literature about forensic aspects of correlation between the height of fall and consequent injuries [6]. The focus of this study was to analyze the correlation between the height of fall and the frequency, type of injuries of certain body regions and organs as well as external injuries. It also aims to determine characteristic injuries of the analyzed body regions in relation to the certain height of fall. Regarding the outcome after a fall from the first floor (defined as 4.8 m), the risk of dying increased [7]. This study used representative data to examine seasonal patterns of fatal falls among persons by gender and age. Although falls are generally believed to occur more often during the winter months, research findings on seasonal patterns of falls and related injuries have been inconsistent [8]. Our study examined records from databases for trends in the rate of fatal falls with age and associated relevant environmental factors.

Materials and methods

In a 2-year period, a total of 4867 autopsies were performed at the Institute for Forensic Medicine of the University of Munich. During this period, 201 patients (4.1 %) sustained fatal injuries as a result of falls. Details concerning the injuries were available from the database in the form of abstracts of the accident. The database records contain information on gender, age, scene findings, survival time, and findings at external examination, autopsy results, and outcome of toxicology, psychiatric history and circumstances at the death scene. Injuries were classified to type and body region. The season of injury was determined by the date of death. Seasons were defined as winter (December–February), spring (March–April), summer (June–August) and autumn (September–November). In addition, information from official reports and police files was evaluated when available. Autopsies were carried out using standard autopsy techniques. Toxicological testing was performed on all deaths at the toxicological laboratory. Specimens routinely collected for toxicological analysis include: blood, urine, brain, liver and kidney, and gastric contents.

Falls were divided into falls from one level to the same level (standing height) and into falls from one higher level to another lower level, dived into a lower (<5 m) and a higher fall level (>5 m).

The study was approved by the Institutional Ethical Review Board of the Institute of Forensic Medicine of the Ludwig-Maximilians University of Munich.

Results

During the 2-year period, a total of 201 persons died of fatal falls in the urban of Bavarian which includes 118 male and 83 female individuals. Concerning the height of fall 111 (55.2 %) cases involved in falls on the same level, 72 (35.8 %) from one level to another lower level less than 5 m, and 18 (9 %) cases from one level to another lower level more than 5 m.

Of the 111 cases, the circumstance of fall was in 2 cases the carpet, in 3 cases bosh, in 2 cases ice skating, in 2 cases, syncope and 34 victims were boozed, in 68 cases the victim's circumstances were unclear. Of the 72 cases, 1 fell in bathtub, 24 out of bed, 17 from bicycles, 2 from motorcycles, 7 from a chair, and 21 down stairs. Of the 18 cases, 1 fell from a tree, one from a mountain, 8 out of a window, 1 from electric pole, 1 from ladder, 1 from horse, and 3 from frame. Two of them committed suicide.

Mean age at the time of death was 66.7 years (range 22–98); in one patient age was unknown, 60.7 % of the fatal falls were older than 65 years of age. In all, 106 patients died in hospital, 56 at home, and 29 on public places, and 10 died in a nursing home, as seen in Fig. 1. The patients who died in hospital the mean hospital abidance was 9.2 days (range 1–120 days).

In the anamnesis in 69 patients, recurrent falls were described. A total of 13 patients needed additives for walking: 5 patients needed crutches, 5 needed wheelchairs, and 5 needed walking frames. One patient was bedridden.

Pre-existing diseases were identified in 120 patients. Four patients had trepanation in the past. Four patients took medication for blood dilution. Twenty patients

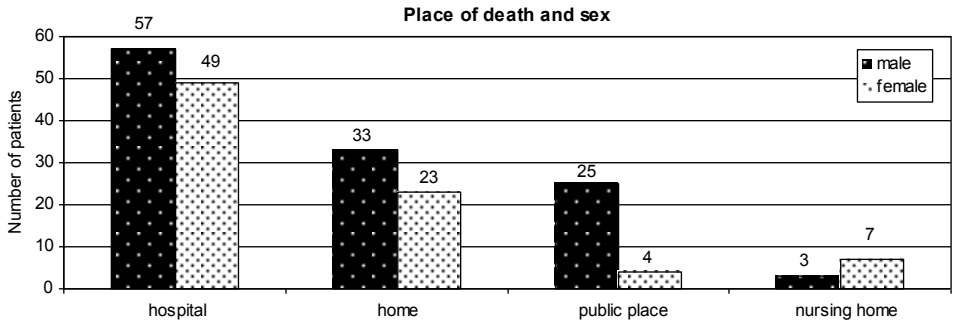

Fig. 1 The place of death in correlation with the sex

were operated because of a fracture of the neck of the femur, one patient suffered of deep vein thrombosis. Four patients were operated 4 weeks ago. Eight patients suffered from malign diseases. In one patient, a blunt trauma of the head was detected. One patient had an amyotrophic lateral sclerosis. One patient was visual handicapped. One was diseased of diabetic mellitus, and seven patients were having cerebrovascular diseases (one with Parkinson, five patients with dementia, one patient with Alzheimer disease). In all, 20 patients suffered from cardiovascular diseases (10 patients with heart insufficiency, 10 patients with hyper tonus). Three patients suffered from bronchopulmonal diseases (two patients with COPD, one patient with asthma). A history of psychiatric illness was present in 40 cases. Psychiatric illness included depression (5 patients), substance abusers (34 patients) and schizophrenia (1 patient).

At the autopsy, external lesions were found in 140 patients: 70 contused lacerations, 34 hematoma, 27 contusions, 4 cuts, 2 excoriations, 1 scalp lesion, and 1 patient had third degree burns.

Sixty-six patients showed fractures of the skeletal system: four had multiple fractures, a sternum fracture twice, 10 patients had rips 5 times, rip-series , skull fracture in 9, basal skull fractures in 18, atlanto-axial dislocation in 5, and fractures of the cerebral vertebral bodies in 3 patients. One patient had a clavicle fracture, two patients had humeral fractures, and three patients had fractures of the femoral neck. Four patients had fracture of the pelvic.

At the autopsy, severe intracranial bleedings were seen in 84 cases. Severe injuries of the internal organs such as aortic rupture in one case, cardiac rupture in one, spleen rupture in two, and hepatic rupture in three cases. Severe lung injuries were seen in 53 cases; blood aspiration with compensatory acute pulmonary emphysema was seen in 30 victims.

Depending on the seasonal pattern in fatal falls, 67 victims died in summer months, 48 in winter months, 47 in spring and 39 in autumn as seen in Fig. 2. A total of 279 causes of death could be detected. The immediate cause of death was in 94 cases head trauma, in 40 cases cardiovascular disease, in 56 cases bronchopulmonal disease, in 3 patients polytrauma, in 5 patients multi-organ failures in the context of a sepsis, and in 3 patients other causes were identified. The correlation between height of fall and cause of death is seen in Fig. 3.

Independent of the height of fall, blunt head trauma was the dominant cause of death.

Discussion

The results of this study show that patterns and extent of injuries are in correlation with fall height. The majority of cases (55.2 %) fell from one level to the same level. Male individuals were involved in the majority of cases (58.7 %) and 60.7 % were older than 65 years of age. Differences in risk-taking behaviors, circumstances, or physical conditioning may be contributing factors. For example, men may be more likely to sustain severe injuries. The gender differences in fatal fall rates have been reported previously [9]. Accordingly, most of the falls from height occurred during “working hours”, an observation that is in the line

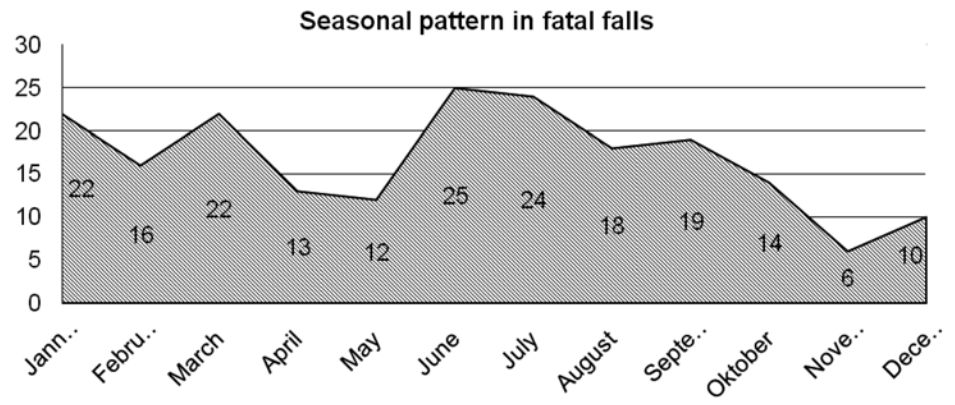

Fig. 2 The seasonal pattern in fatal falls

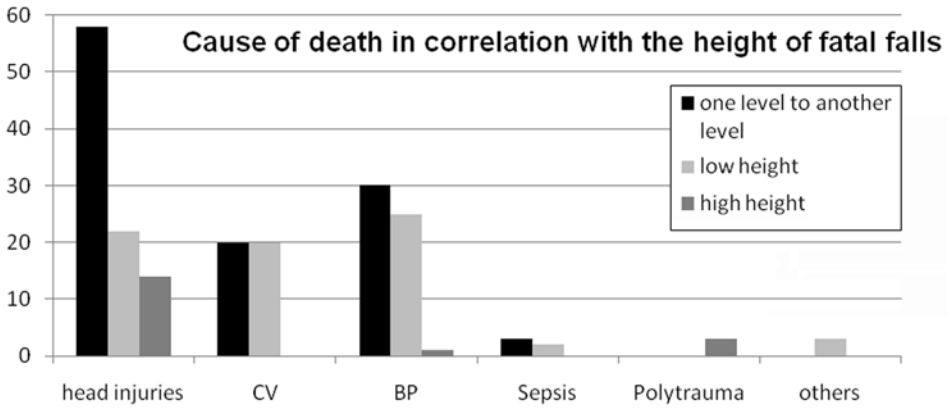

Fig. 3 The cause of death in correlation with various heights

with findings in previous studies [1]. At autopsy, classic findings in falls from height include aortic lacerations as well as fractures of the skull base [5]. Winter weather and/or cold temperatures have been suggested risk factors for falls, but evidence has been inconclusive [8]. The fatal fall rate was higher (33.3 %) in summer months than in winter months (23.8 %)—a difference that was evident for both men and women. Winter temperatures may be associated with more indoor activities and these might explain the lower rates in colder climate. An analysis by Stevens et al. [8] found no seasonal patterns for fatal fall-related injuries. More research is needed to clarify the mechanism underlying these observations. In all, 52.7 % of individuals died in hospital. An explanation might be that most of our subjects fell from one level to the same level and did not die immediately. The shortest survival times were observed for subjects falling from height.

Head injury is an important cause of mortality worldwide [10]. A comparison of the injuries observed in our study with previous results confirms the predominance of head injuries [11]. Dickinson et al. [12] also found that head injuries significantly increase the likelihood of death. Seven patients who fell from one level to the same level had skull fractures. Severe head injuries occurred most frequently in falls on the same level and in falls from height. This finding might indicate that the falling position is changing during a fall, and the falling position often is head. Subdural hematoma (56 %) was the commonest intracranial lesion seen in a total of 84 cases, all basal skull fractures were seen in victims falling from height more than 5 m. Combinations of lacerations and contusions of the brain were seen in falls on the same plane. Fractures of the ribs and vertebrae were the commonest among the non-cranial fractures. Drinking history seems to be associated with a higher risk of all types of fatal falls [13]. Fracture of the long bones is not common. After the brain spleen, liver and cardiac are the most common internal organs involved. Although most falls are predominantly intrinsic, environment factors are often partially responsible as well [14]. For example, loose carpets are often mentioned. At the autopsy, external lesions were found in 140 patients. A total of 59.7 % of victims showed pre-existing illness. In addition, age-related health conditions can result in falls that occur secondary to syncope, vertigo, musculoskeletal disorders, and other physical problems. Physical weakness has been considered to be an important risk factor for falls in older persons aged >65 years.

The risk associated with alcohol may be due to the direct effect as well as detrimental health-related behaviors that may be linked with drinking [13]. Alcohol in combination with comorbid conditions and medication may increase the risk of a fatal injury. In the present study, 16.9 % consumed alcohol, which include 26.4 % female and 74 % male individuals. In a previous study, Preuß et al. [15] found that alcoholisation was an important cause in falling downstairs.

Our investigations had demonstrated that nevertheless head trauma was the most common cause of death, the circumstance of fatal falls and the height of fall could be detected. Special attention should be paid to the external examination.

Conflict of interest

The authors herewith confirm that there are no financial and personal relationships with other people or organizations that could inappropriately influence (bias) this work. There are no potential conflicts of interest including employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

References

1. Türck E, Tsokos M. Pathologic features of fatal falls from height. Am J Forensic Med Pathol. 2004;25(3):194–9.
2. Kohli A, Banerjee KK. Pattern of Injuries in Fatal Falls from Buildings. Med Sci Law. 2006;46(4):335–41.
3. Venkatesh VT, Kumar MV, Jagannatha SR, Radhika RH, Pushpalatha RH. Pattern of skeletal injuries in cases of falls from a height. Med Sci Law. 2007;47(4):330–4.
4. Cross R. Fatal falls from a height: two case studies. J Forensic Sci. 2006;51(1):93–9.
5. Türck E, Tsokos M. Blunt cardiac trauma caused by fatal falls from height: an autopsy-based assessment of the injury pattern. J Trauma. 2004;57:301–4.
6. Atanasijevic T, Savic S, Nikolic S, Djokic V. Frequency and severity of injuries in correlation with the height of fall. J Forensic Sci. 2005;50(3):608–12.

7. Risser D, Bönsch A, Schneider B, Bauer G. Risk of dying after a free fall from height. Forensic Science Int. 1996;78:187–91.
8. Stevens JA, Thomas KE, Sogolow ED. Seasonal patterns of fatal falls and nonfatal falls among older adults in the U.S. Accident analysis and Prevention. 2007;39:1239–44.
9. Kannus P, Parkkari J, Koskinen S, Niemi S, Palvannen M, Jarvinem M, Vuori I. Fall-induced injuries and death among older adults. JAMA. 1999;281(20):1895–9.
10. Bux R, Parzeller M, Bratzke H. Causes and circumstances of fatal falls downstairs. Forensic Sci Int. 2007;171:122–6.
11. Aufmolk M, Voggenreiter G, Majetschak M, Neudeck F, Schmidt-Neuerburg KP, Obertacke U. Unfallchirurg. 1999;102:525–30.
12. Dickinson A, Roberts M, Kumar A, Weaver A, Lockey DJ. Falls from height: injury and mortality. J R Army Med Corps. 2012;158(2):123–7.
13. Sorock G, Chen LH, Gonzalgo SR, Baker SP. Alcohol drinking history and fatal injury in older adults. Alcohol. 2006;40:193–9.
14. Bloem B, Boers I, Cramer M, Westendorp R, Gerschlager W. Falls in elderly Wien Klein Wochenschr. 2001;113(10):352–62.
15. Preuß J, Padosch S, Dettmeyer R. Driever F, Lignitz E, Madea B. Injuries in fatal cases of falls downstairs. Forensic Science Int. 2004;141:121–6.