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New Horizons in Architecture, Planning and Design

İmtiyaz Sahibi / Publisher • Gece Kitaplığı
Genel Yayın Yönetmeni / Editor in Chief • Doç. Dr. Atilla ATİK
Editör/Editor • Prof. Dr. Latif GÜRKAN KAYA

Kapak & İç Tasarım / Cover & Interior Design • Didem S. KORKUT
Sosyal Medya / Social Media • Arzu Betül ÇUHACIOĞLU

Birinci Basım / First Edition • ©EKİM 2019

ISBN • 978-605-8022-90-4

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Baskı & Cilt / Printing & Volume

Sertifika / Certificate No:29377



New Horizons in Architecture, Planning and Design

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INVESTIGATION OF STAIR ACCIDENTS FOR TURKEY

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INVESTIGATION OF STAIR ACCIDENTS FOR TURKEY

Abdurrahman YAĞMUR TOPRAKLI¹

INTRODUCTION

Falling down a stair is common and is often associated with severe injury. Epidemiology is a branch of medical science that examines the distribution of accidents and health related conditions in the community. International articles show epidemiological studies of stair fall and its consequences. In the UK, which has statistical data on stairs, more than 4000 deaths in the 2.5 million emergency home accidents each year result in death. Approximately 230,000 of these accidents and 497 of the deaths are due to stairs (Roys, 2001). Although there are no statistical data in Turkey, 11 fatal accidents have been observed in the last 10 years when the accidents reflected in the media are examined. Considering the time spent with stairs, it can be said that one of the most dangerous places for people are stairs.

Stair Terminology, Human Movement on Stairs and Dimensions

Riser is used to express the vertical length between two steps. The nosing is the part formed by extending the step in the horizontal plane. All steps on the stair must have the same riser height to avoid possible accidents. Tread length can be defined as the horizontal distance between two steps.

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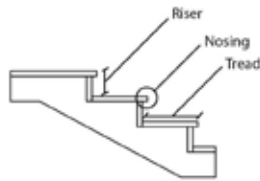


Figure 1: *Stair Components.*

In infancy, the foot shape is similar to a triangle and the fingers are approximately the same length. Foot development is completed by the age of 16 to 18 years. Figure 2 shows the physiological changes of the foot according to age. Body weight is transferred to the floor by means of the feet. Different points of the foot are loaded at different rates. Figure 5 shows load transfers with bare feet and shoes. When the foot is on a flat surface, the greatest load falls on the heels. As the heel lifts up, the load begins to move towards the tiptoe. When a healthy person walks, the feet are at an angle of about 15° with the walking line and there is a 5-6 cm gap between the feet (Figure 4).

When designing a stair, the riser should be calculated by adding shoe size to the bare foot size. One of the most important parameters for the tread is the user foot size. There is not a research for the distribution of users based on measurement of foot size and population in Turkey. Instead, French measures of foot size were adopted. Table 1 shows for the foot age-gender relationship of UK citizens.

Table 1: *The Relationship Between Foot Measures and Age in England (Pheasant, 1996; Roys, 2001).*

Age Range	Male			Female		
	%5	%50	%95	%5	%50	%95
19-25	245	270	290	220	240	260
19-45	245	265	290	215	235	255
45-65	240	260	285	215	235	255
19-65	240	265	285	215	240	255
65-80	235	255	280	210	255	250

To keep in balance, the heel and comb part of the foot must be firmly on the ground. When descending a stair, especially in stairs that have less tread size, the inability of the comb part of the foot to step firmly can cause loss of balance and lead to falls.

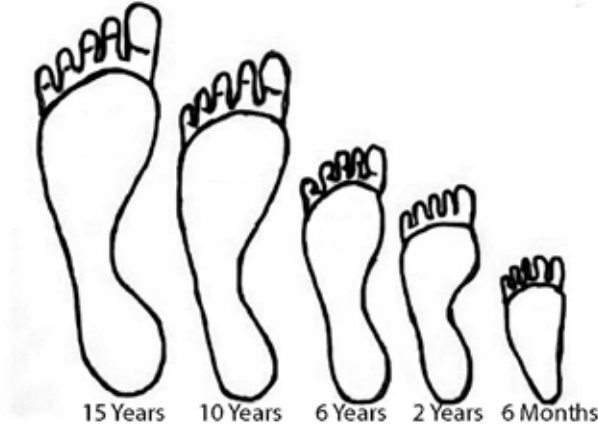


Figure 2: Physiological Structure of Human Foot According to Age (*Ayakkabı ve Saracıye Teknolojisi Ayakkabıda Ölçü Alma*, 2013).

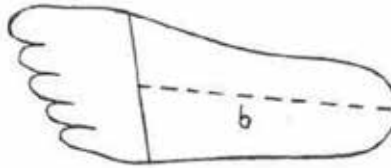


Figure 3: Heel to Ball Measurement (*Ayakkabı ve Saracıye Teknolojisi Ayakkabıda Ölçü Alma*, 2013).

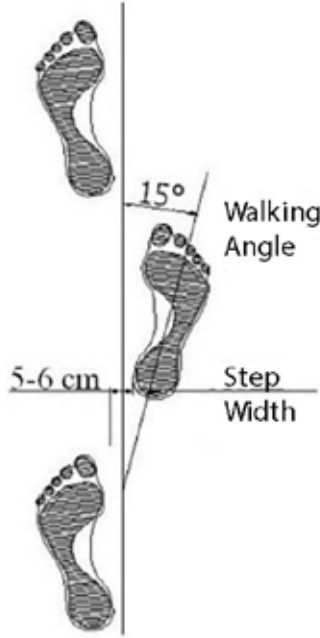


Figure 4: Normal Walk (*Ayakkabı ve Saraciye Teknolojisi Ayakkabıda Ölçü Alma*, 2013).

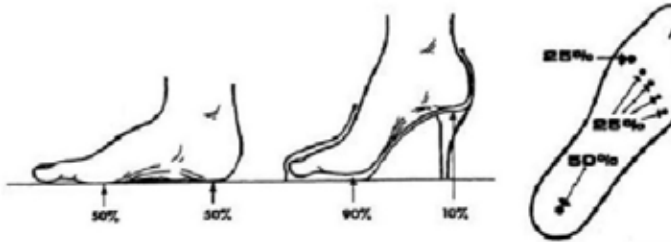


Figure 5: Load Distribution on Foot (*Ayakkabı ve Saraciye Teknolojisi Ayakkabıda Ölçü Alma*, 2013).

When people walk on the stairs, they move much differently than when they walk on a straight path. When descending a staircase - most of the accidents occur at the descent of the staircase - the tiptoe first touches the step. As the center of gravity moves away from the center of

pressure, the balance becomes difficult to achieve, resulting in accidents. When ascending, the front foot moves almost horizontally to the next step. The heel may or may not touch the step. The foot in the back rises from the stair and raises the entire body. In this context, stair descent is more dangerous in terms of user safety. In his pioneering work, Fitch examined the foot motion of a lady wearing heeled shoes through video recording at the descent and ascent of stairs (Fitch, Templer, & Corcoran, 1974). Accordingly, the risk of stair descent is clearly visible (see Figure 6).

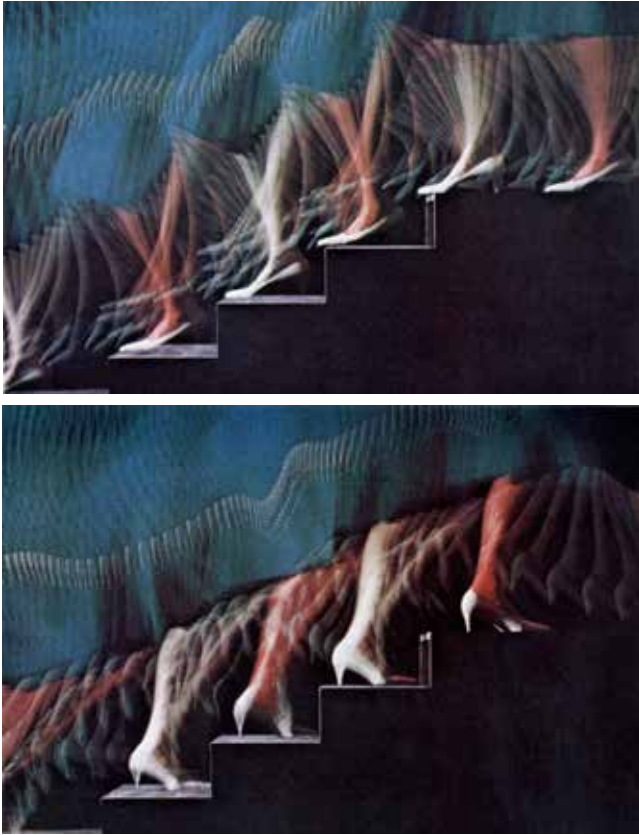


Figure 6: *Foot and Leg Movement at Stair Descent and Ascent (Fitch et al., 1974).*

According to the analysis conducted by Templer et al. with video cassettes focusing on accidents on staircases and the relationship between stair measurements (Cohen, Templer, & Archea, 1985) on vs. off employer's premises, site category, the safest staircase has maximum 15.2 cm (6") riser height and at least 27.9 cm (11") tread length. There are also studies that take into account physiological loads, such as human metabolic rate or heart rate, to achieve appropriate tread / riser combinations when walking on stairs (Fitch et al., 1974).

In his pioneering work, Nagata indicated the difference of stumbling rate between the use of flat shoes and high-heeled shoes on stairs (Nagata, 1995) they are likely to experience mis-steps or to trip. In this paper the perceived difficulty while descending stairs with various tread/rise combinations is evaluated using sensory tests. An index to design tread depth and rise height is found from a multiple regression analysis of experimental results. Ten young males (average age 21.0. According to the analysis of stair-related injury data while walking on stairs, people are more likely to have accidents during stair descent (Nagata, 1995) they are likely to experience mis-steps or to trip. In this paper the perceived difficulty while descending stairs with various tread/rise combinations is evaluated using sensory tests. An index to design tread depth and rise height is found from a multiple regression analysis of experimental results. Ten young males (average age 21.0. In order to develop a rational approach to the design of safer stair sizes, people's shoe sizes should be considered. For women wearing high-heeled shoes, step-edge design is a more critical area (Nagata, 1991).

In this study, firstly, he examined the relation between riser height and tread length in terms of ease of use and described the difficulty experienced by the user in stair use in Figure 7. Accordingly, the figures indicated on the rings

on the chart represent the difficulty expressed by the users. It can be seen here; for Japanese users, the easiest handy tread length is around 30 cm and the riser height is around 15-16 cm (Nagata, 1995) they are likely to experience mis-steps or to trip. In this paper the perceived difficulty while descending stairs with various tread/rise combinations is evaluated using sensory tests. An index to design tread depth and rise height is found from a multiple regression analysis of experimental results. Ten young males (average age 21.0.

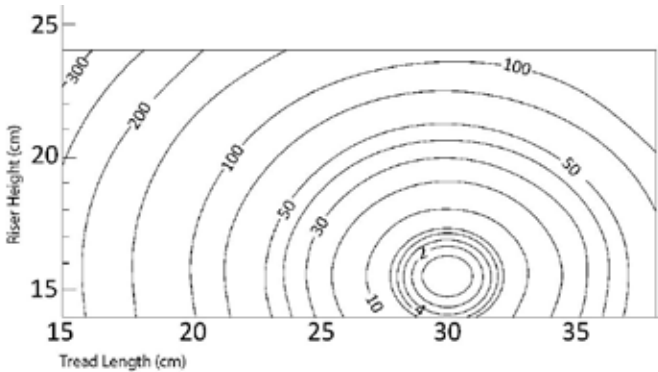


Figure 7: Riser Height / Tread Length Difficulty Index (Nagata, 1995) they are likely to experience mis-steps or to trip. In this paper the perceived difficulty while descending stairs with various tread/rise combinations is evaluated using sensory tests. An index to design tread depth and rise height is found from a multiple regression analysis of experimental results. Ten young males (average age 21.0.

Roys, in his study, mentioned public, semi-public and private spaces in relation to stair riser height and tread length and design differences required by different uses (Roys, 2001). His study also showed the requirements in different areas of use with a graph as can be seen in Figure 8. The values given in the graph are defined as very restrictive, since many people are expected to use the

public stairs at the same time. Semi-public spaces are used by a large number of people, but no density is expected at the same time. A limited number of people use private stairs and are expected to become familiar with this stair. For this reason, restrictions are given more freely.

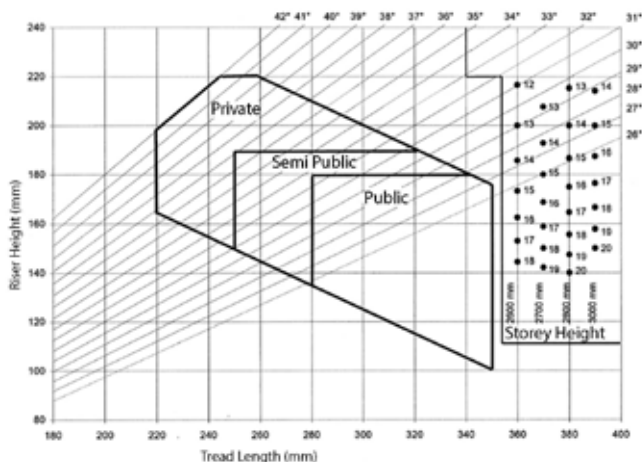


Figure 8: *Acceptable Riser Heights and Tread Lengths (Roys, 2001).*

Causes and Types of Stair Accidents

The three main reasons for stair accidents are; user behavior, lack of maintenance and faulty design. Accidents due to user behavior can be reduced, but because they are user-related, they are closely related to one's characteristics. Although accidents caused by user behavior can be reduced through education, it cannot be very effective unless people change their behavior. Maintenance-related accidents are easy to control and easy to prevent stair accidents. For example, if the step or handrail is not stable, it must be repaired. Similarly, a loose carpet on the staircase can cause a serious accident. Some accidents can be caused by material properties and durability. For example, wood stairs can be damaged by mold over the years. The most accurate and effective

reduction in stair accidents can be achieved by improving design quality. Variable riser height is an example of design faults.

Accidents at the ascent of the stairs are inherently less dangerous (Templer, 1995). This is because the person's center of gravity is slightly ahead. Thus, even if the person falls, he/she is not to suffer much harm. The greater risk occurs during the movement of the rear foot between the two steps. Here, the risk of falling increases as the height of the riser increases. Another risk at the ascent is seen when lifting the body by applying pressure to the floor behind the foot.

Accidents in stair descents are more serious because they can cause the user to fall along the stairs (Templer, 1995). Fractures and head injuries are more common in stair descending accidents (Roys, 2001). If the tread length of the stair is greater than the size of the person's shoes, the risk of falling is reduced. One can scramble the next step, the tip of the toe can slide off the nosing, and these risks increase as the tread length decreases. As tread length decreases, one of two results occurs; Either the person begins to bend his feet outwards, which causes the foot to make a dangerous angle in the direction of walking - or allow his feet to hang at the end of the step. Without one of these, there is a risk that one will not be able to place the foot straight on the step. These situations can cause the person to fall along the stairs. Another risk factor for stair use is the floor friction coefficient. Accordingly, if the relevant coefficient is low, there is a risk of slipping of the foot. If the person allows the foot to hang at the end of the step, there is a high risk that the foot will slide off the lower step. The one falls forward or backward, depending on where the person's center of gravity is and whether or not the one reacts (such as holding onto handrails). Falling back can probably cause serious pain, but not as dangerous

as falling forward. Foster et al. evaluated the importance of emphasizing the edges of the steps. Accordingly, the presence of stripe indicators on the steps, reduce the incidents of heel catch, and tripping for the elderly or visually impaired people. The implementation of this indicator is especially important at the last step. In addition, the position of the indicator appears to be important. It has been observed that the tripping is minimized when the strip is pulled 10-30 mm from the end of the step (Foster, Hotchkiss, Buckley, & Elliott, 2014).

Stairs with low number of steps are more likely to cause stair accidents. According to the investigation made by Jackson and Cohen, %50 percent of the stair accidents seen on stairs with 4 or fewer steps (Jackson & Cohen, 1995). The reason behind this may because people do not pay attention on stairs with low number of risers by comparison with stairs with high number of risers. On first and last three steps of the stairs, a similar result is observed. These steps are the riskiest steps since %60 of the stair accidents seen on these steps (Jackson & Cohen, 1995).

About deficiencies of stairs, Kim and Steinfeld conducted a review by analyzing 578 stairs published on an architectural design magazine and concluded that %61 of these stairs had at least one deficiency (Kim & Steinfeld, 2017) a leading architectural professional journal, over a thirteen-year publication period (2000 to 2012). Considering these stairs seen as “good design” products, stairs on normal use expected to have more deficiencies. This is an important data since it shows the severity of the situation.

One of the most deficiency seen on stairs analyzed in Kim and Steinfeld’s work is missing or unhandy handrails (Kim & Steinfeld, 2017) a leading architectural professional

journal, over a thirteen-year publication period (2000 to 2012). Handrails have a very significant role on preventing stair accidents (Nemire, Johnson, & Vidal, 2016). Size and shape of the handrail is very important to be useful during an accident. The size of the handrail should be 32 to 51 mm (Figure 9).

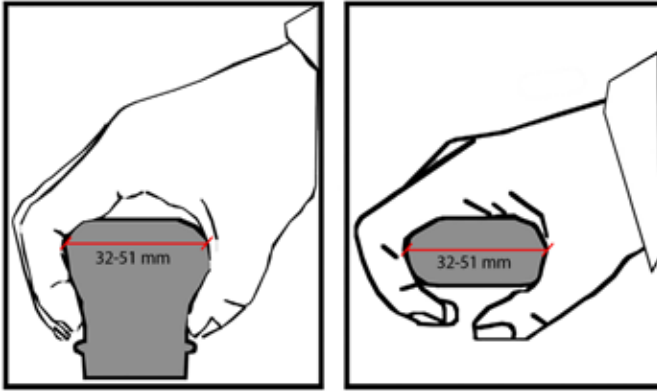


Figure 9: *Optimum Handrail Measurements, adapted from (Nemire et al., 2016)*

The obstacles, objects on the stairs are a common reason of stair accidents. Another cause of accidents is surface of the stair. In some examples, stair surfaces are covered with carpet or similar materials to make stair look more elegant or to make stair slip resistant as can be seen in Figure 10. Nemire et al. put emphasis on slip resistance to lower the accident rates. The risk seen when the cover material or the stabilizer become loose. This situation may lead users to slip, stumble, and trip over the stair.



Figure 10: *An Example of Surface Cover and Stabilizer on Stairs That May Cause Accidents ("Stair Covering," 2017).*

Stair Accidents in Turkey and Numerical Analysis

In the United States, approximately 2100 stair accidents occur annually (*Injury Facts*, 2015) and 1,300,000 entries are made to emergency departments of hospitals (Kim & Steinfeld, 2017) a leading architectural professional journal, over a thirteen-year publication period (2000 to 2012). According to a study conducted in America, 984,000 people were injured as a result of stair accidents in 1996 (*Accident Facts*, 1998). Roys stated that most stair accidents can be prevented by making the tread length more than human foot length (Roys, 2001). According to the British Standards Institute, this length should be at least 280 mm (*British Standards Institute*, 1984). According to

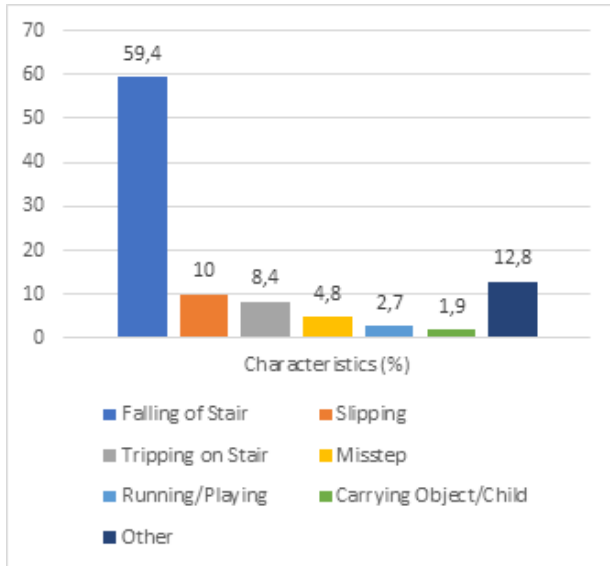
Pheasant, most adults in the UK (except for 24% of men and 2% of women) have feet less than 280 mm (Pheasant, 1996). However, the shoe length can be increased up to 30 cm, taking into account the shoe sole in order to address a larger segment of society. Table 2 shows the characteristics of stair-related accidents in the United States according to emergency records between 1990 and 2012. Accordingly, the risk weights of stair accidents are calculated and given in Table 3.

Table 2: *Characteristics of Stair Related Accidents According to Emergency Records in America from 1992 to 2012 (Blazewick, Chounthirath, Hodges, Collins, & Smith, 2018) 760,843 patients were treated in emergency departments for a stair-related injury during the 23-year study period, averaging 1,076,558 patients annually, or 37.8 injuries per 10,000 United States residents. The annual rate of stair-related injuries decreased by 12.6% ($p < 0.001$).*

Characteristics	≤10 Age	11-60 Age	≥61 Age	Total
Gender	%	%	%	%
Male	55,8	35,7	29,4	37,6
Female	44,2	64,3	70,6	62,4
Location				
Interior	63,1	60,3	63,1	61,2
Exterior	7,2	7,3	10,7	7,9
Unknown	29,7	32,5	26,2	30,9
Ruined Body Part				
Head / Neck	64,9	11,6	23,6	21,6
Arms	13,2	16,3	21,9	16,9
Body	4,2	20,1	22,2	18,1
Legs	16,1	50,9	30,6	42,1
Unknown	1,6	1,1	1,7	1,3
Diagnostic				
Twist	8,6	41,8	16,3	32,3
Soft Tissue Injury	30,1	22,9	22,3	23,8

Fracture	11,4	17,0	34,7	19,3
Tear	26,7	5,5	11,3	9,7
Head Trauma	16,0	3,1	7,2	5,8
Other	7,2	9,8	8,2	9,1
Decision				
Discharged	96,9	96,4	81,5	93,8
Inpatient Treatment	2,5	3,0	18,2	5,7
Left Against Medical Advice	0,5	0,6	0,2	0,5
Unknown	0,1	0,1	0,0	0,1
Cause of Accident				
Falling of Stair	67,9	57,5	59,3	59,4
Slipping	4,5	11,3	9,3	10,0
Tripping on Stair	5,8	8,1	12,1	8,4
Misstep	0,8	4,6	9,1	4,8
Running/Playing	10,4	1,7	0,3	2,7
Carrying Object/Child	1,9	2,0	1,3	1,9
Other	8,8	14,7	8,7	12,8

If the results obtained from the research conducted by Blazewick et al. is reviewed, it can be seen that interior accidents are a lot more common. This may be because people spend more time in home as compared to outside. Results in terms of gender can be interpreted as same way since women spending more time in home. As can be seen in Table 3, most common cause of accident is falling of stairs. This result is connected with the ruined body part result since the legs are expected first to touch the ground when falling of stairs.

Table 3: *Weights of Stair Related Injuries.*

When data from the Turkey Statistical Institute examined, it is seen that there is no data of injury or death from falling off the stairs. When examining the news in Turkey in 10 years between 2009-2019, it is seen that the stair related fatal accidents are subject to the news. The news of falling down the stairs appears to be the subject of news only when there is a recognized person or serious injury other than death. The news of death as a result of falling down the stairs is recorded as falling down the stairs for the elderly, while children are recorded as falling down the stairwell as a result of the wrong railing design. This study is the first study in Turkey since statistics are not kept on the subject. Similar studies are expected to increase in the future. In this study, only accidents that occur as a result of the use of stairs are taken into account, fight or work-related stair accidents are excluded. Accordingly, when Table 4 is examined, it is seen that 11 people have died in accidents caused by the use of stairs in the last 10 years. The fact that 6 of these deaths have been seen in the last three years can be thought

to be related to the removal of related news from news sites as time passes. Here, as with stair accidents in Turkey (see. Table 4), age weight of the accidents (see. Table 5) are given. When the relevant news is examined, most of the death news from falling down a stair are indoor (see Table 6) and, unlike in the United States, the deaths from falling down a Stair are usually men (see Table 7).

Table 4: *Stair Related Fatal Accidents in Turkey (Compiled from News from 2009 to 2019).*

Year	Age	Gender	Location	Result
2010	66	M	Exterior	Death
Detail	“N.D. (66), on the way to his home in the evening, fell on the stairs in the same street he lived by losing balance. Ambulance called by those who saw the incident. N.D. died at the scene determined.”			
Year	Age	Gender	Location	Result
2014	20	E	Interior	Death
Detail	A soldier fell down stairs of a building in Sivas 5th Infantry Training Brigade Command on Sunday, April 20 and diagnosed with cerebral hemorrhage in the intensive care unit of Cumhuriyet University Medical Faculty Research and Application Hospital infantry M.Y. (20) could not be saved despite the interventions.			
Year	Age	Gender	Location	Result
2014	83	E	Interior	Death
Detail	Father of 2 children, K.P. (83) fell on the stairs near his apartment in İzmir, Mehmet Ali Paşa Neighbourhood, Erdem Street No 7.			
Year	Age	Gender	Location	Result
2017	41	E	Interior	Death
Detail	In Safranbolu district of Karabük, the person who fell from the stairs of his house died. According to the information obtained, the man living in İzzetpaşa District, Akseki Street S.Ç. (41) lost his balance on the staircase, which was about 4 meters high inside the house, and fell. 112 teams hospitalized S.Ç. to Safranbolu State Hospital. Despite all the interventions made, the man could not hold on to life. Police launched an investigation into the incident.			
Year	Age	Gender	Location	Result
2017	70	E	Interior	Death
Detail	In a 3-storey building in Eskisehir, the old man died of falling from the stairs. The event occurred in the apartment in Deliklitaş Street. The old citizen (70) fell because loss of balance. Rolled down the stairs and the old man was covered in blood at the door of a lower floor in the apartment.			

Year	Age	Gender	Location	Result
2018	66	E	Interior	Death
Detail	According to the information, R.E. (66) lost his balance and fell from a height of about 2 meters. His head hit the ground seriously injured and hospitalized to Ertürk, Salihli State Hospital by medical teams. After the first intervention here, R.E., was referred to Manisa City Hospital. Despite all the interventions he could not be saved and died.			
Year	Age	Gender	Location	Result
2018	66	E	Interior	Death
Detail	In Gaziantep, due to the elevator is broken, the man tried to climb the stairs to the 5th floor. C.Ö. lost his balance and fell. The unfortunate man died at the scene. The incident occurred in the neighborhood Mehmet Dai Street kolejtepe. Because the elevator was broken in the building he was living in, he climbed the stairs. C.Ö. lost his balance and fell down the stairs. Neighbors heard the sound and found the man lying on the ground. Medical teams arrived to scene determined that C.Ö. died.			
Year	Age	Gender	Location	Result
2018	2	-	-	Death
Detail	B.Y. fell down the stairs of his home in Gaziantep. After 20 days of struggle to survive in the hospital, B.Y. passed away.			
Year	Age	Gender	Location	Result
2019	30	E	-	Death
Detail	Vietnamese national V.D.N. (30), on 3.01.2019, at around 4:30 pm, fell down the stairs in a workplace in Haspolat and was seriously injured. He was receiving treatment in Lefkoşa Dr. Burhan Nalbantoğlu State Hospital, intensive care unit, despite all the interventions on 16.01.2019 could not be saved and died. The autopsy revealed that the cause of death was a skull bone fracture and brain hemorrhage due to falling from a height.			
Year	Age	Gender	Location	Result
2019	86	E	Interior	Death
Detail	One of the old tailor tradesmen in Burdur, R.Y. (86) suffered a brain hemorrhage last Tuesday, from falling down a Stair at his house in the Yenice neighborhood. Since Tuesday, Burdur State Hospital has continued treatment in the Surgical Intensive Care series. R.Y.'s brain death took place in the evening today.			
Year	Age	Gender	Location	Result
2019	33	K	Exterior	Death
Detail	In Bursa Yıldırım District, lost the balance of the stairs falling 33-year-old (A.A.) died in the hospital.			

As can be seen in Table 4 and 5, age is considerably effective on accidents. The age average of stair accident victims is above 50. Novak et al. in their study for evaluating

the age effect on stair accidents, revealed that clear distance between the foot and the nosing is closer for elderly. This leads elderly to have more accidents (Novak, Komisar, Maki, & Fernie, 2016). Other than that elderly more likely to have vision disorders. Brinker et al.'s study revealed that high contrast markings placed on stairs lower the accident ratio for low vision people (den Brinker et al., 2005).

Table 5: *Age Weight of Stair Related Accidents in Turkey (Compiled from News from 2009 to 2019).*

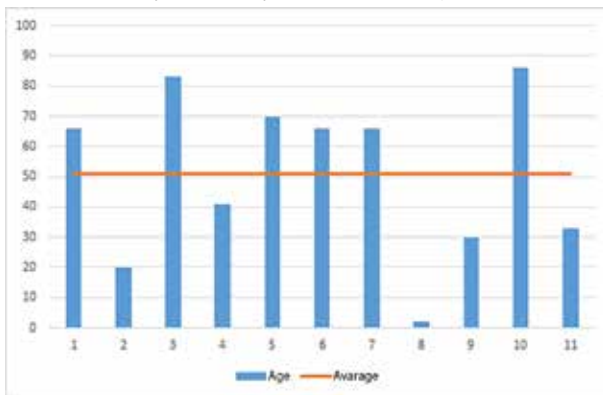


Table 6: *Location Weight of Stair Related Accidents in Turkey (Compiled from News from 2009 to 2019).*

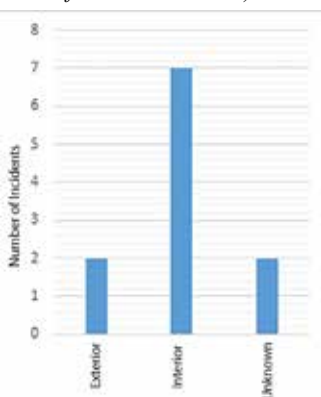
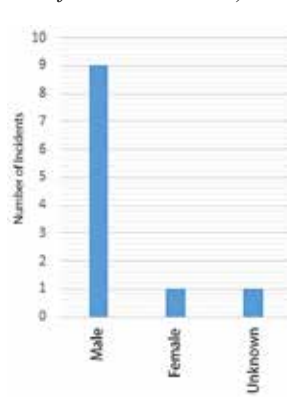


Table 7: *Gender Weight of Stair Related Accidents in Turkey (Compiled from News from 2009 to 2019).*



Stair accident rates in the world are indicated by using the literature. In this study, accident rates are compiled from web news since there is not a statistic on the stair accidents. In order to prevent stair accidents, the most common defects in staircases were revealed and the things to be considered in stair design were determined. Falling down the stairs is high in architectural based accidents. These accidents cause long-term disability and high economic costs, especially for middle-aged or elderly people. Falling down a stair can also lead to a high degree of death or serious injury. In our country, there is no statistical data on injuries and deaths due to falling down stairs. Fatal accidents of falling from a stair in the last 10 years in Turkey shown in Table 4.

Discussion

As a result of the literature study; necessary attention should be given to design of the stairs to prevent accidents caused by faulty design. In the staircase design, user-oriented calculations should be made rather than clichés. The user mass of the Stair should be determined, and the design should be based on the measurements of the human body. When calculating the stair tread, the human foot length should be considered. Calculation methods such as $2a + b = 62$, which do not have test results, may not provide a correct approach to stair design.

Conclusion

The following conclusions can be drawn from the studies seen in the literature.

1. Standard stair heights may not provide an optimal design to ensure safe stair use among individuals with a wide range of capabilities. In the stair design,

the user can use human foot length and so on. The dimensions directly affect the design.

2. Studies on aging and health conditions, cognition, emotion and perception factors also affect the use of stairs.
3. It was found that there are problems in the construction of balustrades, railings on the stairs and problems due to uneven riser heights and lack of visual contrast. (Kim & Steinfeld, 2017) a leading architectural professional journal, over a thirteen-year publication period (2000 to 2012).
4. Depending on whether the staircase will be indoors or outdoors, the coating material should be carefully selected. Accidents can be seen as a result of the wrong choice of coating material, especially in the outdoor and winter months.

Accordingly, it can be estimated that architects' design by considering the above-mentioned issues will be effective in reducing the deaths caused by falls. Statistics about Stairs accidents are not kept in Turkey. With the basic statistical data to be kept, user-based and design-based stair fall risk scale can be developed in future studies and the risk factor of stair designs can be evaluated in this respect. This can contribute to the welfare of the country.

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