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Rethinking the surface design: How to prevent playground related extremity injuries in children

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Abstract
Public playgrounds are specially designed spaces for children to play and develop; however, falls are significant causes of children's injury and are one of the most common mechanisms of injury in emergency departments. The study aims to survey the playground-related mechanism and incidence of extremity injuries in children and rethink the falling surface as designable equipment.
The retrospective observational study enrolled 90 children who are injured in playgrounds and visited the emergency department in Istanbul between 2019 and 2020. Later, an observational study was conducted in public playgrounds within the neighborhood boundaries of the emergency department. The results show that the most common playground equipment related to the injury is slides and the most common surfacing material is rubber. The majority of total injuries were classified as upper extremity, and wrist fractures were the predominant injury type. The result of this study shows even with impact-absorbent surfacing such as rubber, fractures occur in children who fall from a certain height. To prevent these falls, rethinking the surface as designable equipment under high play equipment may help slow the fall.

Keywords
Playground design, Child injury, Falling space, Play equipment, Surface material.

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1. Introduction

More than one billion children live in cities as a result of increasing urbanization in the world (UNICEF, 2012). According to the United Nations, 6 out of 10 children will live in cities by 2025 in developed countries (UNDP, 2000). However, the built environment limits the physical activity of children (Davison & Lawson, 2006; Duncan et al., 2005; Humpel et al., 2004; Saelens et al., 2003; Sallis et al., 1998). Unplanned urban development negatively affects child development and cities are insufficient to meet children's needs. As urban space becomes inefficient and dangerous, children needed gated areas.

According to the researches, it has been revealed that the environment guides children's development they are in during the growth period, and the behavior patterns of the children are determined by the places they are in rather than his personal characteristics (Barker, 1968; Bechtel, 1977; Wicker, 1979). Urban space and children's playgrounds are of great importance in the physical, mental and social development of the child.

Playgrounds are developed to offer child's safe play opportunities in a growingly industrialized society away from traffic and other hazards. They are special spaces to realize the activity of play and have a major role in children's social, cognitive, physical, and psychosocial development (Macarthur et al., 2000; Norton et al., 2004). Playgrounds allow children to recognize themselves and their environment, and help to develop their concentration, sense of responsibility, and social relationships in the community (Chamberlin, 1998). Since play has a great role in a child's life, playgrounds should offer a safe environment. But, if these areas are not designed with significant criteria, they can cause severe injuries and traumas that affect a child's development negatively. Although they do not result in death, they may cause lifelong disability for children.

Safety is an important design problem to be considered in children's playgrounds, and it becomes even more important in playgrounds that appeal to younger age groups. Each year, thousands of children are treated in the emergency departments for playground-related injuries. Approximately 45% have resulted in serious injuries such as severe-fractures, internal injuries, concussions, dislocations, and amputations, and among the nonfatal injuries related to playgrounds, 75%

Figure 1. *Playground equipments and surfacing types such as (1) sand (2) grass (3) dirt and (4) rubber.*

of them occur in public playgrounds (Tinsworth & Mcdonald, 2001).

Ensuring safety in playgrounds depends on play equipment, surfacing, the design of the playground and other elements (Hendricks, 2001). Surfacing has been the focus within playground designs in recent years, as it is defined as the falling space when located under play equipment. The required dimensions and the materials of the falling space differ according to the play equipment (Figure 1). The falling space does not intend to protect the child from injuries, but the surface material may increase or reduce the severity of the injury. However, even with recent impact-absorbent surfacing, such as rubber, which is widely used, playground injuries still occur on a large scale. Therefore, the falling space can be regarded as designable equipment to reduce injuries.

The aim of this study is to determine the mechanism and incidence of injuries related to playground equipment and surfacing, which causes children to be injured most, and recommend design ideas to prevent these injuries. The retrospective observational study enrolled 90 children who were injured in playgrounds and visited an emergency department in Istanbul between 2019 and 2020. Later, an observational study was conducted in eight public playgrounds to examine the equipment types and surfacing materials within the close boundaries of the neighborhood where the hospital locates.

This study centers on the interaction between public playground equipment and the surface type and children's injury and intends to propose design as a tool to prevent these injuries. The remainder of this paper is organized as follows: Section 2 introduces children's playgrounds and related studies. Section 3 gives the data and the method. Section 4 gives the results of the study under (1) extremity injuries in children related to playground equipment and surfacing, and (2) case study of playground equipment and surfacing, Section 5 discusses the results with design recommendations for falling space, and finally, Section 6 gives a conclusion.

2. Children development and playgrounds

Environmental factors affect children from their birth. For the healthy development of children, physical and social environmental factors must meet their needs (Yazıcı, 2004). Children's social environment is first formed by their families, and then by the people they interact with at school and on playgrounds. The socialization of the child is affected by spatial factors as well as individuals. Since the child is the future of society, including children in spatial designs is important for the development of the child and, therefore, for society (Tandogan & Ergun, 2008).

Play is the child's way of integrating with the world (Zengin, 2001). It is the whole of the activities that children develop in their spare time. The child discovers his own nature and abilities with the help of play (Herrington, 1998). Numerous studies indicate the importance of play in children's life. Play enables the child to recognize his emotional, physical, and intellectual potential (Yılmaz & Bulut, 2003). Play encourages children to explore, take risks, learn by doing wrong, and think creatively. Play makes learning fun for the child (Ashton & Lewis, 2001). According to Hüttenmoser and Degen-Zimmerman (1995), retardation was found in the personal and social development of children whose free movement abilities were restricted.

It is argued that children who grow up deprived of the opportunity to play outdoors have neurotic personalities in the future, as their instinctive energies are aggressive due to the suppression of their bodily and cognitive energies (Koptagel, 1978). The child needs natural play environments; natural play environments are diverse, abstract from the concept of time, and provide more freedom (Prescott, 1987). Due to the benefits of play in child development, children's playgrounds are indispensable in urban spaces.

Furthermore, certain researches indicate that the built environment restricts the physical activities of children and young people (Davison & Lawson, 2006; Duncan et al., 2005; Humpel et al., 2004; Saelens et al., 2003). Lack of physical activity in children is considered one of the most important risks that will lead to future diseases, such as heart failure (Andersen et al., 2004). Children's playgrounds are key places that will help increase physical activity. Thus, to support these developments, they must be safe and not cause further injury.

2.1. Safety in children playgrounds

Safety is a critical design problem to be considered in children's playgrounds. It becomes even more important in playgrounds that appeal to small age groups. According to the National Program for Playground Safety (1996), most playground-related accidents occur as a result of children playing with play equipment that does not appeal to their age group. Thus, children fall from higher elements and get injured.

Falls are an important cause of playground-related children's injuries and are one of the most common mechanisms of injury in emergency departments. A growing number of researches have emerged in recent date literature on playground-related injuries. Some studies have researched the role of surface materials on safety, while different studies have searched for falls related to playground equipment. Falls are regarded as 25%-52% of all treated child injuries (Migneault et al., 2018), and 67% of playground injuries are caused by falls from equipment to the ground (Chalmers et al., 1996). Out of the 147 children who died from playground-related injuries between 1990 and 2000, 31 of them were a result of falls to the playground surface (Tinsworth & Mcdonald, 2001).

Playground-related injuries mostly depend on fall height and surface area, with 2.6-3 injury odds for fall height, and 2.3-18.2 injury odds for surfaces (Chalmers et al., 1996; Laforest et al., 2001; Macarthur et al., 2000; Mowat et al., 1998). Studies have shown that playground equipment higher than 150 cm has higher injury rates (Ball, 2002; Phelan et al., 2001; Vollman et al., 2009). Another study revealed that equipment above 200 cm has a nearly 2.56 times higher injury rate compared to equipment lower than 150 cm (Laforest et al., 2001). The same study indicates that the injury risk is similar for play equipment heights of less than 1.5 m and 1.5-2 m; however, the risk increases 1.5 times for equipment higher than 2 m (Laforest et al., 2001). Non-impact-absorbing surfaces such as asphalt and concrete have a greater risk of injury compared to impact-absorbing surfaces, such as sand, rubber, and gravel (Chalmers et al., 1996; Howard et al., 2009; Mott et al., 1997; Sosin et al., 1993). Although children's mortality rate due to a fall is unusual, the hospitalization ratio is high (Khambalia et al., 2006). Almost three million children who fall apply to the ED every year and related injuries are the second major cause of pediatric hospitalization (Committee on Injury and Poison Prevention, 2001). Suecoff (1999) showed that playgrounds in low-income areas host more hazards than high-income areas because of rusty play equipment and damaged fall surfaces.

Mott et al. (1997) stated that the risk of injury due to a fall from monkey bars was 2 times greater than the climbing frames and 7 times greater than the swings or slides. Bae et al. (2017) indicated that out of 6.110 children who were injured in a playground, 40,5% were related to slides, and 18% were related to swings. Concussions were associated with children aged 0-2 and swings, while hand and arm fractures were associated with children aged 3-7 years and climbing elements. Horizontal bars, stretched ropes, and trampolines were mostly related to foot and leg fractures.

Critical fall height for a playground is the maximum height of fall from play equipment to the ground and is measured through impact testing, which evaluates the shock-absorbing properties of surfacing material. Equipments higher than 60 cm require an impact-absorbing surface under them and the critical fall height of the surfacing must be equal to or greater than the play equipment's fall height, while the fall height should not exceed 300 cm (BS EN 1177, 2018; TS EN 1176-1).

In the United States, ASTM (American Society for Testing and Materials Standards) creates playground surfacing standards for public playground surfacing to prevent severe injuries. In Public Playground Safety Handbook (CPCS, 2015) which complies with the ASTM standards, the critical fall height of different play equipment is defined. The Handbook divides playground users into three groups: Toddlers (0-2 years of age), preschool children (2- to 5-years-olds), and school-age children (5- to 12-years-olds), and it offers maximum heights for age-appropriate equipment. In general, the maximum height of equipment according to age groups is 81 cm high for toddlers, 150 cm high for 2-5 years old, and 240 cm high for 5-12 years old. Pivot points of swings should not be more than 240 cm, the same height is valid for slides. According to the handbook, some equipment is not recommended for some age groups, such as balance beams for toddlers.

In Turkey, TS EN 1176 Series standards have been accepted and published as Turkish Standards to determine the safety conditions for children's playgrounds. Accordingly, the maximum fall height for the swing should be ≤ 1500 mm, for the carousel it should be ≤ 1000 mm, and for the seesaw, it should be ≤ 1500 mm. The standards indicate that the free fall height can be up to 3000 mm with the appropriate surfacing thickness (Turkish Standard Institute, 2018).

In the context of playgrounds, the shock absorbance of a surface has gained more importance in recent years to prevent injuries caused by falls from a certain height. Shock absorbing refers to impact attenuating, which is directed to the reduction of head injuries. The maximum HIC (Head Injury Criterion) value is 1000 and the g-max value is 200 for impact protection materials on playgrounds (ASTM Standards F1292-13). A shock-absorbing surface aims to reduce head injuries as well as other playground-related extremity injuries.

There are different surface materials used in playgrounds that are shock-absorbing. Some of them are loose-fill materials such as gravel, sand, rubber mulch, and wood chips. Rubber mats, tiles, and other poured-in-place materials are unitary materials. Every material has a different shock-absorbing ability. The installation depth standards of the surfacing and height of the play equipment differ according to the ability. Some of the materials are accepted as a good fall-attenuating surface material, while others are more dangerous if the fall height within the playground is greater than a certain number of meters.

Certain studies have reported results for impact attenuation of playground surfaces. Over the years, the results of the studies differ according to material performances that improve over time. Ramsey and Preston (1990) focused on the Impact Attenuation performance of wood mulch, wood chip, sand, and gravel, and manufactured mats, asphalt, and concrete as playground surfacing. Lewis et al. (1993) aim to evaluate playground surfaces with respect to impact attenuation and resulted that wood chips were the best alternative rather than sand, grass, gravel, and synthetic mats. Mack et al. (2000) studied loose-fill playground surfaces and their result indicated that shredded rubber was better than sand, wood fibers, and wood chips; while pea gravel was the poorest. Recent studies show that bark surfacing, such as rubber mulch, is the safest material for playgrounds with high fall risk (CPSC, 2015; Davidson et al., 2013). Also, wood chips, sand, and pea gravel are no longer appropriate to use as playground surfacing because they are not accessible in compliance with the Americans with Disabilities Act. According to Public Playground Safety Handbook, grass and dirt are not recommended as surfacing under playground equipment (CPSC, 2015).

Fractures commonly occur in almost one-third of children (Cooper et al., 2004), and certain types of fractures may unfortunately have negative consequences for children's future bone health. Fractures may result in nerve damage, decreased strength, related joint suffering, anxiety, and even depression (Morzaria, 2016). It may also prevent children from certain activities for the rest of their lives, which may result in developmental delays. A study showed that children who suffered from forearm fractures had lower bone strength compared to other children, and lower bone strength further results in future fractures from weakened bone (osteoporotic fracture) (Farr et al., 2014). Especially children over 10 years who were injured by fractures had long-term negative effects, thus suggesting not tolerating such dislocations (Zimmermann et al., 2004). On the other hand, younger children may have development problems if they suffer from growth plate injuries, and can have crooked or slightly longer or shorter arms or legs (Kruse & Dubowy, 2018).

Certain researchers have studied the relationship between psychological-behavioral characteristics and fractures in children. Stancin et al. (2001) examined child and family outcomes of pediatric traumatic fractures and observed functional limitations in children and increased family stress after the child injury, especially with lower extremity fractures resulting in more negative impact. Zheng et al. (2014) compared children hospitalized for fractures with a control group of children without fractures, and found that more children displayed more psychological and behavioral problems in the fracture group than in the control group with higher scores for restlessness, aggression, depression, and violation of discipline. A recent study demonstrated that long bone fractures result in fear of falling thus limiting participation in physical activities, anxiety about aesthetic appearance, post-traumatic stress disorder, acute stress disorder and depression, and impacting social life by restricting certain activities (Singaram & Naidoo, 2019). Considering all these long-term negative effects, it is important to prevent playground injuries.

Children's injuries and fractures are important preventable causes of morbidity and mortality (Baker et al., 2015), and long-bone fractures indicate more severe injuries (Cryer et al., 1990). Although certain studies support risky play for children's development, mental health, and physical health (Brussoni et al., 2012; Engelen et al., 2013; Sandseter & Kennair, 2011); it has also resulted in injury or even death (Brussoni et al., 2015). Therefore, safety against falls is the primary criterion to be considered in a playground design. Studies indicate that even if the surfacing material improves, the injuries continue to happen. Apart from materials, designers can produce other solutions by using design as a tool to prevent these injuries.

3. Method and case study

Two important risk factors for playground-related injury are the height of the play equipment from which the children fall, and the surface material where they fall (Chalmers et al., 1996; Macarthur et al., 2000). Therefore, this study focuses on (1) the injury type after the fall and (2) the surface material where children land. It later demonstrates a case study to further investigate public playgrounds in terms of play equipment and surface material.

3.1. Method

This study focused on cases of children with playground equipment and surfacing as the cause of injury. In this study, 90 children who were injured during a play in a public playground between June 2019 and December 2020 and applied to the emergency department of a Level 1 trauma center were examined retrospectively. The data was extracted from ED visits for falls in children to 18 years of age, and descriptive statistics were used to notify the frequencies of injuries. All ED visits from June 2019 and December 2020 were manually reviewed. All children who presented with a fall in a public playground were included. Subsequent visits for the same falls suffered by children with a head injury and minor bruises were excluded. Injured children were retrospectively examined by gender, age, injury-inducing factor, injury mechanism, injured body part, injury-causing playground equipment type, and surfacing material. There was no 2-year-old child and no children older than 14 years of age among the patients who were registered as playground injuries.

In the case study research, an observational technique was used at a total of eight public playgrounds present in the close neighborhoods of the emergency department. Playgrounds were

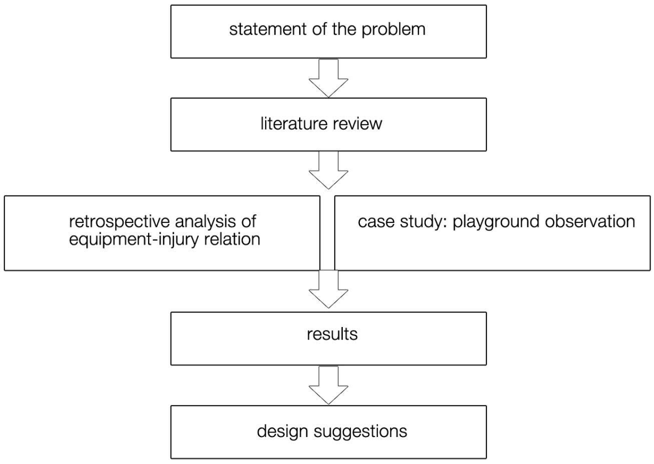

Figure 2. *The flow diagram of the study.*

examined according to equipment type and surfacing material in terms of flexibility. The playgrounds in Istanbul are not diverse and usually use the similar mass-produced play equipment. For this reason, the case study playgrounds give similar information about the general and are selected for observation (Figure 2). This study was reviewed and approved by the Research Ethics Board from the local institution.

3.2. Research area

Istanbul is the most populated city in Turkey, and it continues to receive migration from all over the country due to its economic and cultural opportunities along with health services. The problems caused by rapid population growth and unplanned urbanization are intensely experienced, and children cannot adequately meet their needs because of the decreasing amount of public green areas. As a result of population growth and urbanization, green areas lose their characteristics and are assigned different land use. An increase in traffic load makes the streets of Istanbul more dangerous for children. The social and cultural development of the child is negatively affected by isolation from the urban space.

Sancaktepe district has become a center of attraction and is one of the districts that suffered the most from the intense immigration from other cities. Sancaktepe is located on the Anatolian side of Istanbul, with Çekmeköy in the north, Kartal and Maltepe in the south, Sultanbeyli and Pendik in the east, and Ümraniye and Ataşehir in the west. The district was named "Sancaktepe" in the 2009 local elections and was formed by the merging of Samandıra, Sarıgazi, and Yenidoğan Districts in 2009. A large part of the district is located within the boundaries of the Ömerli Drinking Water Basin. Its proximity to strategic points such as Sabiha Gökçen Airport and highways has made the district spatially important.

Sancaktepe has a population density above the average of Istanbul, with its total population, and almost one-third of the population consisting of children under the age of 18 (Tepe, 2018). The district has 19 neighborhoods with 80 public parks; some of them have public playgrounds. Although public playgrounds exist numerically, their

Figure 3. *Sancaktepe District in Istanbul.*

quality is debatable. Children cannot adequately meet their needs for development, and they also experience injuries. The emergency department of the Level 1 trauma center where the study was conducted is located in the Emek Neighborhood in Sancaktepe District. Meclis, Emek, and Sarıgazi Neighborhoods are examined in terms of public playgrounds (Figure 3). Eight different public playgrounds were used for observations of surfacing materials. The types of playground equipment and surface materials are listed. Each playground had a variety of equipment different in height. Observations were recorded through photographs and notes.

4. Results

4.1. Extremity injuries in children related to playground equipment and surfacing

In total, 90 playground-related incidents were examined. Females and males equally accounted for 50% of playground-related injuries. There was one child as a toddler, twenty-three children in the 2-5 age group, and fifty-nine children in the 6-12 age group. Two children were 13 years old and five children were 14 years old. One male child was in a toddler group. In the 2-5 age group, 69% accounted for females, while 66% of children above 5 years old were males. %69 of injuries in the 2-5 age group and 83% of injuries above 5 years old were classified as an upper extremity.

The playground equipment involved in injuries was slides (35.6%), swings (18.9%), monkey bars (17.8%), teeter-totters (8.9%), and spinners (4.4%). 14.4% of all injuries occurred while running. The majority of total injuries (80%) were classified as an upper extremity (Figure 4). Wrist fractures were the predominant injury type, accounting for 27.8% of all injuries, followed by elbow fractures (22.3%), soft tissue traumas (16.7%), forearm fractures (10%), fractures of the ankle (6.7%), foot fractures (4.4%), shoulder fractures (3.3%), hand finger fractures (2.2%), thigh fracture (1.1%) and leg fracture (1.1%). Also, there are 4 children with multiple fractures, two of them have a fracture of both wrists (2.2%), one of them had elbow and ankle fractures (1.1%) and one of them had elbow and wrist fractures (1.1%).

The largest proportion of wrist fractures occurred on slides (36%), followed by swings (24%), monkey bars (16%), and teeter-totters (8%). 16% of wrist fractures occurred while running. Elbow fractures were the predominant injury type on slides (40%), followed by swings (20%) and monkey bars (20%) equally, and teeter-totter (5%). 15% of elbow fractures occurred while running. Soft tissue traumas are distributed more evenly between play equipment. They occurred on monkey bars (26.7%) and while running (26.7%), followed by slides (21%), slides (13.3%), monkey bars (6.6%), and spinner (6.6%). Forearm fractures occurred most frequently on slides (22.3%), monkey bar (22.2%), and teeter-totters (22.2%), followed by swing (11.1%), spinner (11.1%), and while

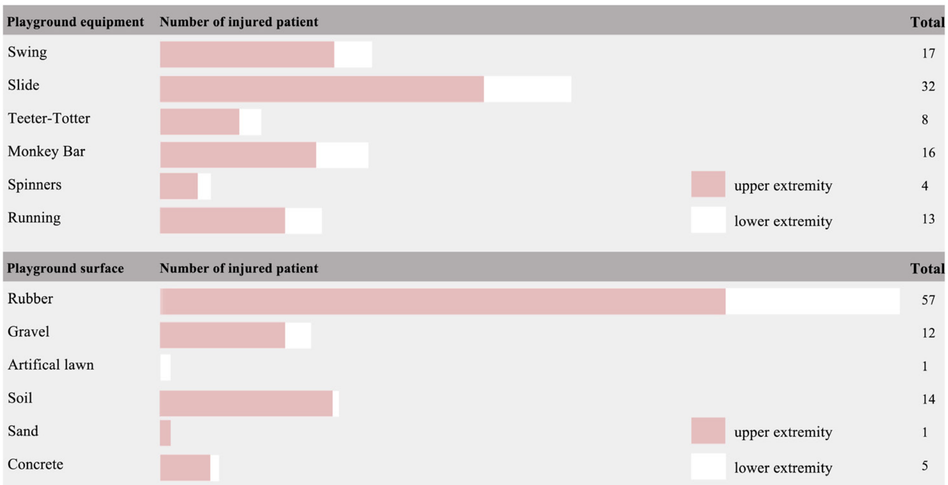

Figure 4. *The amount of injuries depending on the play equipment and surfacing.*

running (11.1%). The majority of ankle fractures occurred on a swing (33.3%) and teeter-totter (33.3%), followed by monkey bars (16.7%) and while running (16.7%). Foot fractures were the predominant injury type on the teeter-totter (50%), followed by slide (25%) and spinner (25%). Shoulder fractures occurred on slides (66.6%) and spinner (33.4%). Hand-finger fractures occurred on the slide (50%) and swing (50%). A thigh fracture occurred on the slide, and a leg fracture occurred on the swing. The playground equipment involved in both wrist fractures was the slide. The child with elbow and ankle fractures is reported to fall from the slide; while another child with elbow and wrist fractures fell from the monkey bar.

The largest proportion of injuries (57 of 90 [63.3%]) occurred on rubber surfaces followed by soil (14 of 90 [15.6%]), gravel (12 of 90 [13.4%]), concrete (5 of 90 [5.5%]), sand (1 of 90 [1.1%]), and artificial lawn (1 of 90 [1.1%]) (Figure 5). This also reflects distribution of the surface material in public playgrounds in Istanbul. The largest proportion of wrist fractures occurred on rubber (29.9%), followed by elbow fractures (21%), soft tissue traumas (12.3%), forearm fractures (10.6%), ankle fractures (8.8%), foot fractures (5.3%), shoulder fractures (5.3%), and thigh fracture (1.7%), leg fracture (1.7%), hand finger fracture (1.7%) and both wrist fractures equally (1.7%). In soil, wrist fractures (28.5%) and soft tissue traumas (28.5%) occurred equally, followed by elbow fractures (21.4%) and forearm fractures (14.2%). Reported multiple trauma injuries, including both elbow and wrist fractures have occurred on soil surface. Wrist fractures (33.3%) and elbow fractures (33.3%) were the predominant injury type on gravel, followed by soft tissue traumas (25%). Reported multiple trauma injuries, including both elbow and ankle fractures have occurred on gravel. On concrete, an elbow fracture, a hand finger fracture, a forearm fracture, an ankle fracture, and a soft tissue trauma occurred equally. The playground surface material involved in poly-trauma with both wrist fractures was sand. Lastly, the injury that occurred on the lawn was a foot fracture.

On the rubber surface, the injuries occurred most frequently on slides (40%), swing (15.9%), and monkey bar (%15.9) equally, followed by teeter-totter (14.1%), running (8.8%), and spinner (5.3%). On soil, out of 14 injuries, they occurred most frequently on a swing (28.5%) and monkey bar (28.5%) equally, followed by slides (21.5%), running (14.3%), and spinner (7.2%). Out of 12 injuries, running was the main mechanism of injury (33.4%) on gravel, followed by swing (25%) and slide (25%) equally, and monkey bar (16.6%). Running (40%) was most commonly involved in a total of 5 injuries reported on a concrete surface, followed by swing (20%), slide (20%), and monkey bar (20%) equally. Lastly, the slide was the only equipment involved in injuries on sand and lawn.

4.2. Case study of playground equipment and surfacing

As mentioned in previous chapters, injuries are closely related to the surfacing materials of the playgrounds. After the retrospective observational study in the emergency department, the purpose of the case study documentation was to determine the physical characteristics of the playgrounds in the close neighborhood, as sample public playgrounds in which

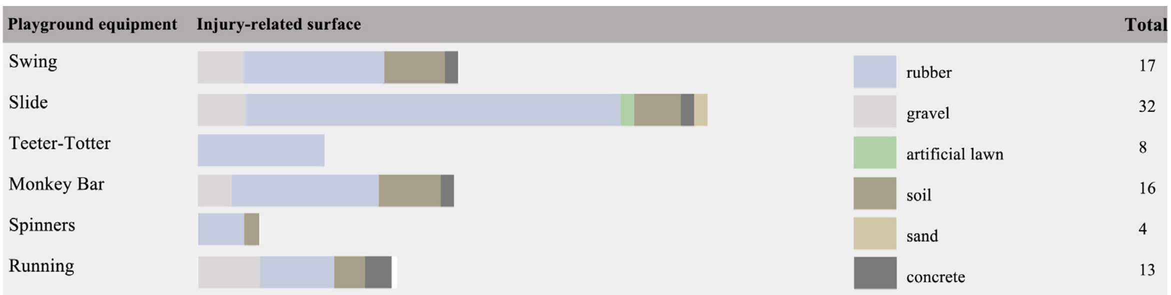

Figure 5. *The injury relation between play equipment and surfacing material.*

children were injured in.

The case study was conducted in Emek, Meclis, and Sarıgazi Neighborhoods of the Sancaktepe District. Sancaktepe has a population density above the Istanbul average and shows rapid population growth. Therefore, the safety of public playgrounds is important for densely populated districts. In total, there are thirteen parks; eight of them have public playgrounds within their boundaries (Figure 6). These public playgrounds which are located in the neighborhood of the research emergency departments are selected to examine as example playgrounds in order to show the equipments and surfacing material.

The emergency department is located in the Emek Neighborhood, with five public parks; three of them have public playgrounds. Meclis Neighborhood has five public parks, and only two of them have public playgrounds. Sarıgazi Neighborhood has three public parks and all of them have public playgrounds.

A total of eight public playgrounds were evaluated. All the playgrounds had similar mass-produced play equipment; swing, slide, teeter-totter, and climbing chain. All the equipment was

Figure 6. *Case study public playgrounds and photographs.*

made of plastic and iron material. The most abundant equipment was swings and slides, each park possessed both equipments (100%). There was no teeter-totter in one playground (12.5%). Five of the playgrounds had climbing equipment (62.5%).

All the playgrounds had rubber surfaces under the play equipment. The surrounding of the play area was hard surface (natural stone and concrete) in six playgrounds (75%), and grass (soil) in two playgrounds (25%). There was no sand, artificial lawn, or gravel in the playgrounds.

All playgrounds have similar equipment and surfacing. A composite structure, which is formed by the combination of several play equipment, is often observed in case study public playgrounds. Apart from these, no adventure playgrounds or large free spaces with creative equipment have been documented.

5. Discussion

In this study, the primary focus was to survey the mechanism and incidence of injuries and to show the relationship between play equipment, surfacing material, and traumatic extremity injury types. The safety of children's playgrounds has several factors, most importantly the type and height of the play equipment, and the ability of the surface material to absorb the energy of a child's fall.

The results show that the most seen mechanism of injury is a fall from the slide, followed by a swing, monkey bar, teeter-totter, and spinner. The play equipment with a certain amount of height is mostly involved in injuries. It is also found that the largest proportion of injuries occurred on the rubber surface, followed by soil, gravel, concrete, sand, and artificial lawn, respectively. The reason for the high rate of a rubber surface is that it is the most used surface material under play equipment in Istanbul.

According to previous studies, injuries in playgrounds are mostly associated with climbing equipment, swings, and slides; the most common injury type was falling, and the most commonly affected body part was the upper extremities (Bae et al., 2017; Migneault et al., 2018; Phelan et al., 2001). In the present study, the number of injuries from slides was nearly equal to the sum of the swings and monkey bars. The most common injury type was upper extremity injuries, similar to those shown in previous studies. The majority of the injured children had fractures due to falling, and all of the equipment was somehow involved in the injuries. Wrist fractures and elbow fractures account for almost half of the upper extremity injuries.

Since the majority of injuries were caused by falls, the impact-absorbing surface is one of the most important safety factors. The reason for the high risk of fractures among children who fall from climbing equipment is due to a lack of physical maturity and ability, and they may not have enough reflexes and muscular systems to play safely on these high structures (Migneault et al., 2018). Due to these falls, it has been studied for many years to make the surface have an injury-preventing ability. There can also be other design solutions to convert the surface from material to equipment. The results re-emphasize the insufficiency of surfacing under high play equipment in public playgrounds.

In this study, approximately one-sixth of all injuries were not related to any play equipment and occurred while running in the playground. This shows that not only play equipment but also all other furniture and surfaces on the playground should be included in the safety policies.

When the injury rate by age group is examined, it has been observed that most fall-related injuries occur in children over 5 years of age (5-14 years old). Children playing with equipment that is not suitable for their age may cause these injuries because public playgrounds usually have mass-produced play equipment where children of all ages play. Accordingly, further research is recommended on the cause of these injuries and the design of playground equipment. As a result of the study, design recommendations were developed that will provide optimum safety.

5.1. Design recommendations

Although height is significantly connected to injuries, it is a part of equipment design related to fun, which attracts children. Thus, the results from multiple viewpoints suggest an advanced surfacing to minimize the risk of injury. This led to a number of following recommendations for public playgrounds in relation to safety to guide designers and planners (Figure 7):

- Creating artificial topography, especially for slides may provide falls from height. Embankment slides might be a safer alternative for multi-age playgrounds.
- Playgrounds intend to serve children of all ages, but the importance of age-appropriate equipment in playgrounds is revealed in mentioned literature. It is highly recommended to label the equipment to give age appropriateness of the equipment to the users.
- Safety standards for play equipment that mostly cause injuries, which are slides, swings, and monkey bars, should be re-evaluated. Especially the height of the equipment can have limitations, and the surfacing can be replaced with more flexible alternatives. Thus, predominant injury types due to falls, especially wrist fractures, can be reduced.
- Rather than selecting similar mass-produced play equipment, different affordable alternatives can be used to support creative play with different surface design ideas.
- Rubber mulch is the safest surfacing according to review studies, but lead is present in recycled rubber and the health safety is still questionable. Recent work has shown that rubber mulch as a surfacing material in playgrounds offers minimal risks with a reduction in injury risk (Fawkes et al., 2021). However, there is still increasing concern about other chemical components. Alternative solutions could be healthier for children.
- Many children are reported to fall while running. For this reason, the safety of the surface material in the rest of the public playground should also be discussed along with the material under the play equipment.
- Rethinking the surface under high play equipment more flexibly may slow the fall. The falling space can be regarded as designable equipment.

Most importantly, the observations supported the previous studies' results that even if the rubber is used, the serious level of post-fall injuries shows the surfacing is not sufficient for safety. Hence, this study suggests flexible equipment, such as a trampoline play system and safety net, as an alternative surfacing under high play equipment. Bouncing systems can be included in play equipment or surface design. These systems can absorb the energy of

Figure 7. *Artificial topography and nets as prevention through design.*

a fall and can reduce the severity of a possible injury.

According to CPSC, the critical fall height of 0.2 m-depth loose-fill surfacing are 3 meters for wood chips, 2 m for wood mulch, 1.5 m for pea gravel, and 1.2 m for sand, whereas 3 meters for 0.15 m-depth shredded rubber (2015). Compared to loose-fill materials' critical heights by CPSC, trampoline systems can be an alternative impact-absorbing surfacing where there is a critical fall height higher than 3 meters. They can be installed to varying depths in order to comply with critical fall heights. There are trampoline systems that are 30 times more shock absorbent than shock pads (Oz, 2022).

On the other hand, safety nets are mash ropes designed to absorb the energy of a fall, thus preventing a possible injury. In some public playgrounds where the equipment height is greater than 2 m, designed surfaces embedded with nets can help slow the fall. According to BS EN 1263, safety nets can allow a maximum fall height of 6 meters (2014). The Standard addresses that if the fall height is greater than 2 meters, the safety nets should be larger than 35 square meters.

A limitation of the present study is that only compiled data from one selected hospital were used, thus it cannot represent Istanbul metropolitan. The number of participants could be increased. However, the results of the present study are relatively admissible as the public playgrounds in Istanbul are very similar to each other. It can be anticipated that other public playgrounds may also lack adequate safety standards. Istanbul has a population of nearly 20 million; therefore, this study may show a small part of a large ratio of the actual injured children population.

This study has several strengths. First, there is no multidisciplinary study that includes Landscape Architecture and Orthopedics and Traumatology Department, which gives data about the accidents that took place in playgrounds and their consequences in Turkey. This study aimed to make a numerical contribution. Second, it linked playground conditions and injuries, including equipment and surfacing type. Third, the study demonstrated that the rubber was not sufficiently safe under high play equipment in public playgrounds. Finally, it offered a different perspective and presented the falling space as an element that can be designed outside of the material.

Public playgrounds are used by more children at the same time, which can be a factor in most accidents and need further research. Increasing such multi-disciplinary studies conducted with the trauma department is important for demonstrating real results, thus allowing for other design solutions and contributing to the literature.

6. Conclusion

This work has shown that even with impact-absorbent surfacing such as rubber, fractures occur in children who fall from a certain height. To reduce injuries, design can offer a new approach to this problem by reconsidering the falling space, and rethinking the surface as designable space under high play equipment to help slow the fall.

The design has a role in influencing the behavior of the children to reduce injury while maintaining the fun and risk that is important for their development (Wakes & Beukes, 2012). As researches show that the risk of height-related injury is notably decreased when the height of play equipment is below 1.5 m (Ball, 2002; Phelan et al., 2001; Vollman et al., 2009; Wakes & Beukes, 2012), it is highly recommended to include play equipment below 1.5 m height in public playgrounds. Higher equipment needs advanced flexible falling spaces, which designers should focus on, as illustrated in Figure 7.

In Turkey, local governments are not obliged to comply with the standards in the recruitment of playground equipment. The control of the compliance of the equipment with the current standards can only be carried out during the purchase process, but the control of the playground elements in terms of safety requirements during and after the installation is incomplete. This is another factor that endangers the safety of playgrounds.

Children are usually brought to the hospital without stabilization of injured extremities. Moreover, some of these fractures can be serious and need surgery treatment. It is important to avoid these falls as much as possible because they can lead to permanent disability in children.

In conclusion, the result of this study points out that the surface material is a key factor in playground safety, and to reduce the risk, the surfacing should be soft and thick enough to absorb the energy of a child's fall. A series of recommendations have been made for designers and decision-makers of playgrounds based on this research. They use some already available elements that can be interpreted as surfacing alternatives with regard to children's falling space. On the other hand, with improvements in technology, new materials could make playgrounds safer for children, and designers can also ultimately assess the opportunity to see the falling space as more flexible play equipment. Consequently, it is hoped that, with more extensive studies and inclusive and descriptive legal frameworks in the future, these recommendations will reduce injury rates.

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