Trampoline-related Injuries in Children: A Tertiary Pediatric Center Experience in Israel

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ABSTRACT **Background:** The growing popularity of trampoline jumping in the past years has led to an increase in trampoline-related injuries. The risk is particularly high in large trampoline parks, which are attended by many individuals of various sizes and ages.

Objectives: To describe a tertiary pediatric center experience in Israel.

Methods: The database of a tertiary pediatric medical center was retrospectively reviewed for all trampoline-associated admissions to the emergency department in 2015–2018. Data were collected on patient demographics and injury characteristics with an emphasis on type and venue.

Results: Of the 23,248 admissions for orthopedic trauma during the period, 244 children were admitted for 246 trampoline-related injuries. Injuries involved the lower limb in 130 children (53%), upper limb in 87 (36%), spine in 20 (8%), and other sites in 9 (3%). Almost half of the injuries (113/246, 46%) were fractures, 27% required either closed or open reduction in the operating room. Large trampoline centers were responsible for half of the cases.

Conclusions: Trampoline injuries accounted for 1.05% of all emergency department admissions at a tertiary pediatric hospital in 2015–2018. Nearly half of the trampoline-related injuries were fractures. Large trampoline centers pose a potential risk for more serious injuries. We raise awareness of the risks of trampoline jumping, considering increasing popularity of trampoline parks, and encourage the authorities to implement safety regulations.

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Trampolines were introduced in 1936 by a circus acrobat [1] and popularized for recreational use in the 1950s. Recent years have witnessed a rapidly growing interest in their use [2], accompanied by a consequent increase in the incidence and severity of trampoline-related injuries [3]. Large indoor and outdoor trampoline parks are particularly dangerous because of the large jumping spaces they offer and the many individuals, often of various ages and sizes, participating at the same time [4,5]. According to the National Electronic Injury Surveillance System (NEISS) of the U.S. Consumer Product Safety Commission, the rate of trampoline-related fractures was 30.1% in 1990–1995, 31.7% in 2000–2005, and 29% in 2002–2011 [6,7]. Studies from other countries reported fracture rates of 37% in Austria [8] and 29% in South Korea [3]. Choi et al. [3] also presented a summary of previous studies in which fracture rates reached 80.5%.

The literature today continues to describe trampolines as a potentially harmful recreational activity and describes the risk factors for injury, such as a younger age, lack of protective pads and a net, multiple jumpers at once who are different age and size [1,3,5,9]. In our medical facility, we identified another risk factor: large trampoline centers. We did not find enough research regarding this specific and growing risk factor [3,10]. The aim of the present study was to describe the experience of our tertiary pediatric medical center and to evaluate the impact of large trampoline centers on the nature of those injuries.

PATIENTS AND METHODS

The electronic database of Schneider Children's Medical Center of Israel was retrospectively reviewed for all admissions to the emergency department for orthopedic trauma between October 2015 and November 2018. Schneider Children's Medical Center is a tertiary pediatric medical center. The center accepts all children in accordance with a public medical policy in Israel. There are 550,000 admissions per year, about 130,000 are trauma related admissions.

Using a keyword searching tool, we identified all records that included the word *trampoline* in various forms. Data were then collected on patient demographics, chief complaint, history, findings on physical examination and imaging, venue of injury, site and type of injury, diagnosis, treatment, and follow-up recommendations. Fractures were further evaluated for type, treatment, and potential long-term complications. Severe fractures were defined as fractures that were displaced and treated by either open or closed reduction and fixation and/or that posed a risk to normal bone growth.

The study was approved by Rabin-Beilinson (Petah Tikva, Israel) ethics committee.

STATISTICAL ANALYSIS

Categorical variables are reported as a number and percentage. Continuous variables were evaluated for normal distribution using histogram and Q-Q plot. Continuous variables are expressed as median and interquartile range (IQR). Categorical variables were compared between groups using chi-square test or Fisher's exact test. All statistical tests were two sided, and $P < 0.05$ was considered as statistically significant. Statistical analyses were performed using IBM Statistical Package for the Social Sciences statistics software, version 25 (SPSS, IBM Corp, Armonk, NY, USA).

RESULTS

Of the 23,248 admissions to the emergency department for orthopedic trauma from 2015 until 2018, 254 (1.05%) were trampoline-related injuries. Ten were second referrals for the same complaint.

DEMOGRAPHICS

The cohort included 244 children, 124 boys (51%) and 120 girls (49%), aged 9 months to 17 years (median 8 years). Eighty-seven children (36%) were younger than 6 years, 112 (46%) were aged between 6 and 12 years, and 43 (17.8%) were older than 12 years. The male-to-female ratio was the same in all age groups (1.0:0.9, $P = 0.732$).

SITE OF INJURY

A total of 244 children were admitted for 246 injuries. The injuries included 87 to upper limbs (36%), 130 to lower limbs (53%), 20 to the spine (8%), and 9 to other sites (such as head or face) (3%) [Figure 1]. There was no difference between male and female patients in the distribution of sites of injury (upper limb $P = 0.941$, lower limb $P = 0.297$, spine $P = 0.939$, other, $P = 0.172$).

The upper-limb injury rate was 30% (26/87) in the < 6 year age group, 46% (52/112) in the 6–12 year group, and 23% (10/43) in the > 12 year group. Corresponding values for lower-limb injury were 65%, 41%, and 58%. Children in the 6–12 year group had significantly more upper-limb injuries than the other age groups ($P = 0.008$), and children in the < 6 year age group had significantly more lower limb injuries than the other groups ($P = 0.002$ [Figure 2].

Figure 1. Area of injury

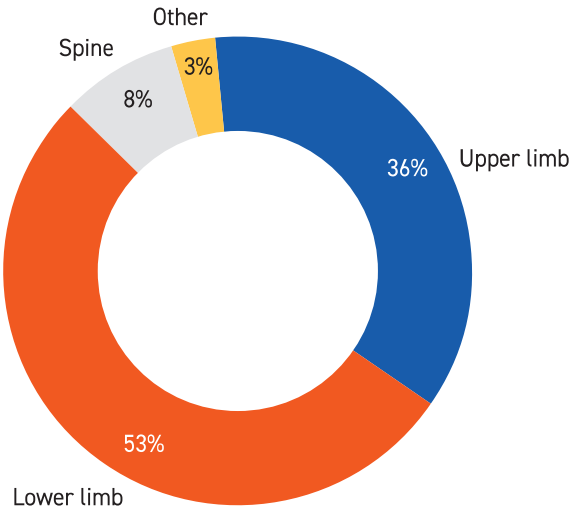
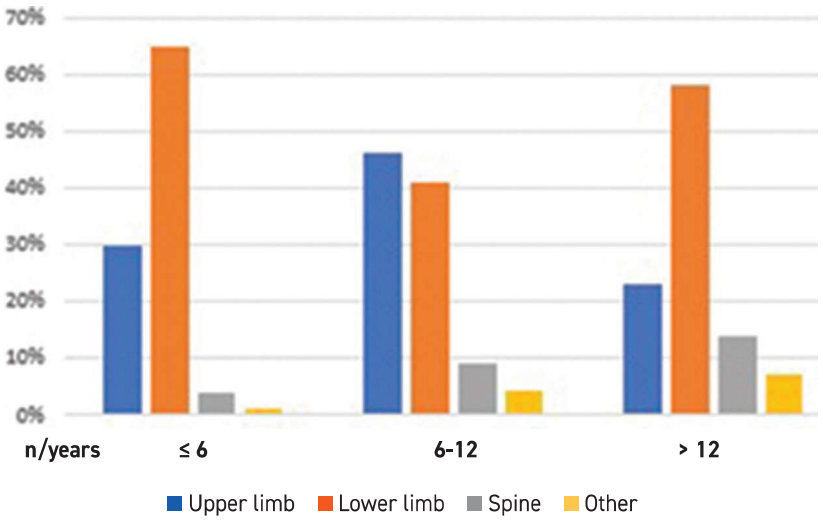


Figure 2. Area of injury in age groups

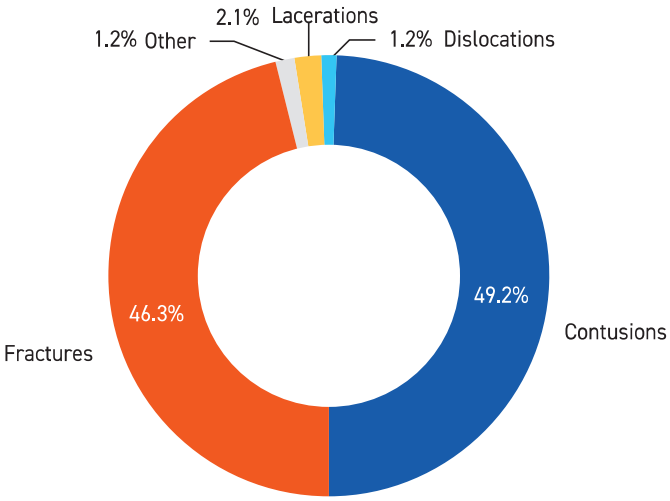


TYPE OF INJURY

Simple injuries such as contusions, strains, and lacerations, were documented in 120 children (50.8% of cohort), mainly contusions or strains (49.2%), and a few lacerations (1.2%). Fractures were diagnosed in 113 children (46.3%); 5 (2.1%) were due to dislocations; 3 (1.2%) to other reasons [Figure 3].

Breakdown by fracture type yielded 84 simple (non-epiphyseal) fractures (73.7%), 28 epiphyseal fractures (24.8%) including 19 (16.7%) Salter-Harris grade I or II and 9 (7.9%) Salter-Harris grade III or IV, and 2 open fractures (1.8%), including one tibia midshaft and one ankle fracture, Salter-Harris grade 3. Children younger than 6 years of age had significantly more total fractures than children in the two older age groups (P = 0.02). Children older than 12 years old had more lacerations and dislocations than the two younger age groups (66.7% of lacerations, 60% of dislocations) but the findings did not achieve statistical significance.

Figure 3. Type of injury



TREATMENT

Of the 113 children with fractures, 82 (73%) required a cast without reduction, 15 (13%) required closed reduction and a cast, and 16 (14%), with severe fractures, underwent either closed or open reduction and internal fixation. The remainder were treated either with an elastic bandage, sutures, and closed reduction for joint dislocations or received no treatment at all.

COMPLICATIONS

Long-term follow-up because of concerns of a growth disturbance was recommended for 54 children (22.1%). By follow-up at 1 to 2 years, no growth disturbances were noted.

Eight children who underwent surgery for severe fractures had postoperative complications. They included persistent pain and range of motion limitation in two, and infection, arthrofibrosis (knee joint), anterior interosseous radial nerve apraxia, refracture within 6 months, varus malunion, and complex regional pain syndrome in one patient each.

VENUE OF INJURY

Data on venue of injury were available for 92 children (37.7%). Forty-two (45.7%) were injured at home or at a small playground and 50 (54.3%) were injured at a large trampoline park. Most of those younger than 6 years of age were injured at home (n=33, 78.7%; $P < 0.001$) compared to the other two groups, and most of the children older than 6 years were injured at a trampoline park (6–12 year group, n=33, 69.7%; > 12 year group, n=25, 80.0%; $P < 0.001$ compared to the youngest group). There was no difference in the limb affected or type of injury by venue of injury.

Although not statistically significant, we found a larger number of severe injuries among the children injured at trampoline parks (18.4%) rather than at home or at a playground (7.1%).

By treatment, of the 42 injuries sustained on trampolines in the home or playground, 18 (43%) were treated with a cast, 8 (19%) with a bandage, and 3 (7.1%) with closed reduction/closed reduction-internal fixation/open reduction-internal fixation (CR/CRIF/ORIF); 12 (28%) did not require treatment. Of the 49 injuries sustained at a trampoline park, 14 (28%) were treated with a cast, 14 (28%) with a bandage, and 9 (18.4%) with CR/CRIF/ORIF; 10 (20%) did not require treatment.

INJURY TRENDS

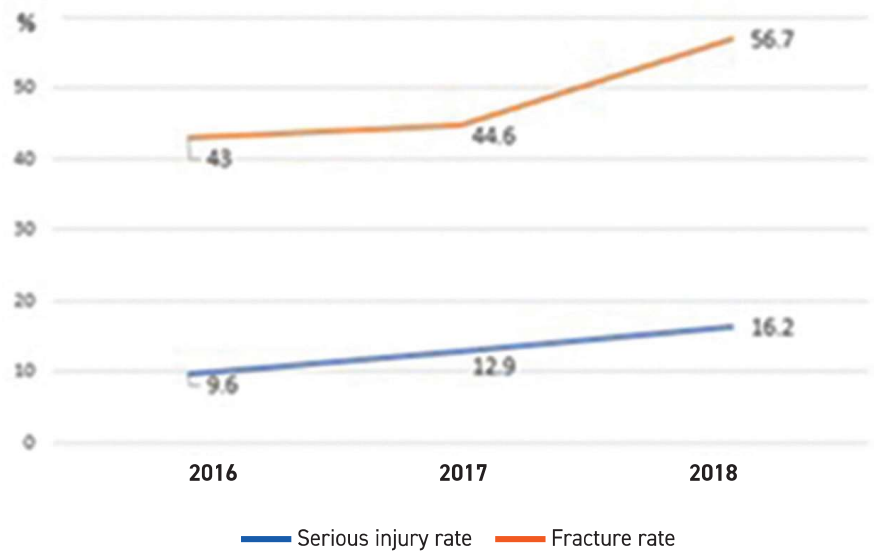
Analysis of the number of injuries by year showed that 84 injuries occurred in 2016, 85 in 2017, and 74 in 2018. Fracture rates were 43% and 44.6% in the first two years compared to 56.7% in 2018 (P = 0.212). Corresponding severe fracture rates (serious injury) were 9.6% and 12.9% compared to 16.2% in 2018 (P = 0.485) [Figure 4].

DISCUSSION

The growing recreational use of trampolines [1-3,6,8] has raised concerns among medical staff, emergency departments, and pediatric orthopedists. Several studies have reported a steady increase over time in hospital admissions for trampoline-related injuries [1,6]. In several studies, trampoline-related injuries accounted for 1.0–1.7% of all hospital admissions [1-3,6], while the rate of hospitalization, according to Purcell et al. [1], was second only to injuries from Alpine skiing. Between 2000 and 2009, 22 deaths in the United States were attributed to a trampoline-related injury [3]. Ibrahim and Okoro [11] found that the intervention rate (inpatient treatment/outpatient treatment/transfer to another facility) for trampoline-related injuries was the same as that for other mechanisms of injury, such as road accidents and falls from a height.

In this present study, the rate of admission for a trampoline-re-

Figure 4. Fracture rate and severe injury pattern during the research years



lated injury was 1.05%, within the range of earlier reports [1-3,6].

In line with other studies [3,4,6], we found that children < 6 years old sustained significantly more fractures than older children (P = 0.02). We also found that children in the < 6 year age group had significantly more lower-limb injuries than the other groups, and children in the 6–12 year group had significantly more upper-limb injuries than the other age groups. In other studies, the most prevalent injury site was the lower limb [3,6,8], but did not subdivide to age group as in this paper.

Although the difference was not significant, injuries sustained in large trampoline parks were often more severe than injuries that occurred at home or in small playgrounds (18.4% vs. 7.1%). It might reflect an increasingly alarming trend. The risk of fracture is especially high in trampoline parks where the jumping area is large and younger children may use the trampoline simultaneously with an older child or an adult. When a person lands on trampoline, the potential energy is converted into elastic kinetic energy or recoil. If there are two people jumping, and the lighter person lands just after the heavier person, the kinetic energy from the heavier person is converted into propulsive force onto the lighter person. Therefore, the lighter the child, the greater the velocity, the greater the chance of injury. This transfer of energy, termed kipping, is used by professional coaches to increase and the height of athletes during training [12]. We suspect that the many jumping pads and the structure of the facilities may invite stunts and somersaults.

Nevertheless, in many countries, the number and popularity of those centers has increased tremendously in the past 3 years. A study from Australia found that three new facilities for trampoline jumping open every month [13], and in South Korea, 76% of all trampoline-related injuries occurred in trampoline parks, and the rate of fractures was higher [3]. Jesse et al [10] also reported a higher rate of fractures in commercial trampoline centers, in an adult and pediatric population. In Israel, the number of new trampoline parks has increased from 1 to 20 over the last 5 years.

In our facility, there was a considerable increase in the fracture rate over the 3-year study period, from 43% to 56.7%, and an increase, albeit not significant, in the rate of severe injuries. We can hypothesize the increase in injuries is related to the increased amount of trampoline parks, but there are too many variables to test this directly and correctly.

To counter this trend, the American Academy of Orthopedic Surgeons recommended that children younger than 6 years of age not be allowed to play on trampolines [14,15]. In addition, several pediatric and orthopedic societies in some countries [1,3], including Beterem in Israel [9], have established rules for trampoline use: only one child jumping at a time; if several children are jumping together, they should be of similar age and size; construction of safety net surrounding trampolines; close parental supervision (although one study showed that 71% of the injuries occurred with an adult present [5]), and placement of shock-absorbing pads. Ladders should not be used, and children should be discouraged from performing somersaults and other stunts while jumping.

However, the effect of these recommendations in reducing the injury rate remains unclear. Wilson et al [16]. evaluated the impact of the Canadian Pediatrics Society advisory against the use of trampolines at home, published in 2007 and reaffirmed in 2013, on trampoline-related injuries sustained at the IWK Health Center in Halifax, Nova Scotia. They found that the rate of injuries had increased, from 0.9% to 1.6%. Therefore, we suggest that a more proactive approach to trampoline-related injuries, such as supervision in facilities and community safety programs, should be considered.

The present study was limited by our inability to calculate the exact trampoline-related injury rate because we do not know the exposure rate. In addition, the study was based on a retrospective review of medical records, such that some of the data for a portion of patients were missing.

CONCLUSIONS

Further studies are needed to corroborate our findings and to reach more definitive conclusions in terms of risks and prevention.

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We all have our time machines.
Some take us back, they're called memories.
Some take us forward, they're called dreams.
Jeremy Irons (born 1948), English actor and activist

Capsule

Malaria plastic parasites elude control

Malaria parasites, *Plasmodium spp.*, are genetically plastic and resistant to control efforts despite–or possibly even because of–their complex life cycles. Public health interventions could therefore have effects beyond the induction of drug resistance. **Early** and co-authors applied a modeling approach, supported by genomics, to *Plasmodium falciparum* obtained in French Guiana to determine how control efforts might influence the parasite's life cycle. Only sexual forms of *P. falciparum* can infect mosquitoes and be transmitted to new hosts, but only asexual forms can replicate and amplify in humans. As the number of human cases declined, the authors found that the most strongly selected genes were enriched for the transcription factors required for sexual development. Higher rates of sexual conversion that lead to greater transmission potential from humans to mosquitoes, which could undermine the impact of control measures.

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Eitan Israeli