ORIGINAL ARTICLE

Trampoline injuries

M Nysted, J O Drogset

Br J Sports Med 2006;**40**:984–987. doi: 10.1136/bjsm.2006.029009

See end of article for authors' affiliations

Correspondence to: M Nysted, Department of Orthopaedics and Rheumatology, St Olavs Hospital, Trondheim University Hospital, Olav Kyrres Gate 17, 7006Trondheim, Norway; mona.elvebakk@stolav.no

Accepted 11 September 2006
Published Online First 25 September 2006

Objective: To describe the mechanism, location and types of injury for all patients treated for trampoline-associated injuries at St Olav's University Hospital, Trondheim, Norway, from March 2001to October 2004.
Materials and methods: Patients were identified from a National Injury Surveillance System. All patients were asked to complete a standard questionnaire at their first visit at the hospital. Most data were recorded prospectively, but data on the mechanism of injury, the number of participants on the trampoline at the time of injury, adult supervision and whether the activity occurred at school or in another organised setting were collected retrospectively.
Results: A total of 556 patients, 56% male and 44% female, were included. The mean age of patients was 11 (range 1–62) years. 77% of the injuries occurred on the body of the trampoline, including falls on to the mat, collisions with another jumper, falls on to the frame or the springs, and performing a somersault, whereas 22% of the people fell off the trampoline. In 74% of the cases, more than two people were on the trampoline, with as many as nine trampolinists noted at the time of injury. For children <11 years, 22% had adult supervision when the injury occurred. The most common types of injuries were fractures (36%) and injury to ligaments (36%). Injuries to the extremities predominated (79%), and the lower extremities were the most commonly injured part of the body (44%). A ligament injury in the ankle was the most often reported diagnosis (20%), followed by an overstretching of ligaments in the neck (8%) and a fracture of the elbow (7%). Regarding cervical injuries, two patients had cervical fractures and one patient had an atlantoaxial subluxation. Three patients with fractures in the elbow region reported an ulnar nerve neuropathy. 13% of the patients were hospitalised for a mean of 2.2 days.
Conclusion: Trampolining can cause serious injuries, especially in the neck and elbow areas of young children. The use of a trampoline is a high-risk activity. However, a ban is not supported. The importance of having safety guidelines for the use of trampolines is emphasised.

Trampolines have become popular during recent years, and the number of injuries has increased with the popularity.[1] Whether there is an actual increase in the risk associated with trampoline use for the same number of hours of exposure is not known. The marked increase in trampoline injuries might reflect only the increased number of trampolines now available for recreational use or the creative manner in which they are being used. Smith[1] studied the epidemiology of trampoline-related injuries among children and concluded that they were so common that children should not use trampolines. Furnival *et al*[2] and Woodward *et al*[3] found a dramatically increasing number of trampoline injuries, and recommended a ban of the recreational use of trampolines. In 2000, Brown and Lee[4] reported that trampolines were responsible for >6500 paediatric cervical spine injuries in the USA, and supported a ban of the use of trampolines by children.

In 2002, The Norwegian Directorate for Civil Protection and Emergency Planning estimated that there were between 90 000 and 100 000 trampolines for recreational use in Norway. Figures from the Norwegian National Injury Surveillance System (NISS) at The Norwegian National Institute of Public Health indicate that the annual number of trampoline-related injuries in Trondheim increased from 24 in 1997 to a peak of 160 in 2001 (fig 1).

This study was performed because we noticed that the number of trampoline-related injuries seemed to increase during spring 2001. The purpose of this study was to describe the mechanism, location and types of injury for all patients treated for trampoline-associated injuries at St Olav's University Hospital from March 2001 to October 2004.

MATERIALS AND METHODS

All patients with trampoline-related injuries treated in the emergency department at St Olav's University Hospital, Trondheim, Norway, from March 2001 to October 2004 were included. Trondheim is the third largest city in Norway, with 154 351 inhabitants in 2004 including 31 955 children. A total of 12 007 children were <6 years, and 19 948 were between 6 and 15 years old. St Olav's University Hospital serves as the only local hospital in our area, and is also the regional hospital for central Norway, receiving all multiply injured patients from a population of 630 000 inhabitants. The accident and emergency department has around 18 000 consultations every year.

The patients in this study were identified from the database of NISS at the Norwegian National Institute of Public Health. From 1990 to 2004, NISS registered all injured patients at the emergency department in our hospital. Inpatient and outpatient data were collected from the hospital and the accident and emergency department. No other facility in Trondheim treats serious injuries, and all injuries should therefore be recorded.

All patients or their parents completed a standardised questionnaire regarding the circumstances of the current accident at their first attendance at the hospital. The attending doctor added details of the diagnosis and the severity of the injury. The injuries were classified according to the Abbreviated Injury Scale (AIS), which gives a severity score ranging from 1 (minor) to 6 (unsurvivable).[5] In cases where the patients had been unable to complete the questionnaire, the information was found in the medical records. Personal data on each patient, the circumstances of the accident, the time of admission to the hospital, the body part injured, the diagnosis, treatment and the numbers of days in hospital were recorded prospectively. All patients received another questionnaire at follow-up regarding

Abbreviations: AIS, Abbreviated Injury Scale; NISS, National Injury Surveillance System

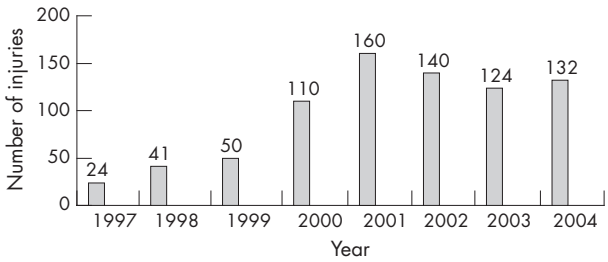

Figure 1 The numbers of trampoline injuries in Trondheim 1997–2004.

the mechanism of injury, the number of participants on the trampoline at the time of injury, adult supervision and whether the activity occurred at school or in some other organised setting. These data were collected retrospectively. We received answers to this questionnaire from 244 (48%) of the patients. The prospective questionnaire from NISS had a 100% response. Regarding the mechanism of injury, most of the patients had described the circumstances of the accident in the standardised questionnaire from NISS. Regarding the number of participants on the trampoline at the time of injury, adult supervision and whether the activity occurred at school or in some other organised setting, we have uncertain results because of the lower response. The questionnaires were converted into a database using SPSS V.12 computer software. Descriptive statistics with frequency measurements for categorical variables were used. The χ^2 test was used to examine group differences. The significance level was set at $p<0.05$.

RESULTS

Between 2001 and 2004, 556 patients were treated for trampoline-related injuries. This represented around 3% of all injuries in our accident and emergency department.

All injuries occurred on a regular-sized trampoline except two, which occurred on a minitrampoline. There were 56% males and 44% females. Mean age was 11 (range 1–62) years; 13% of the patients were between 1 and 5 years old, 40% were between 6 and 10 years old, 34% were between 11 and 15 years old and 13% were >15 years old.

Most of the injuries (77%) occurred on the body of the trampoline, and included falls on to the mat, collisions with another trampolinist, falls on to the frame or the springs, or when performing a somersault, whereas 22% were injured after falling off the trampoline (table 1). The number of trampolinists on the mat at the time of injury was recorded in 268 (48%) instances. More than two people were on the trampoline at the same time in 74% of the cases, with as many as nine trampolinists noted at the time of injury in one case. Adult supervision was reported for 40%. For children <11 years, 22% had adult supervision when the injury occurred. Preventive measures were recorded for 40% of the cases, including padded trampoline frames in 36% and security nets in 4%.

The most common types of injuries were fractures (36%) injury to ligaments (36%), contusions (20%), lacerations (7%) and dislocations (1%). Fractures were more common in children <10 years 125 of 295 sustained a fracture, compared with the older jumpers, where 76 of 261 patients had a fracture ($p = 0.001$).

The most commonly injured parts of the body were the lower extremity (44%), upper extremity (34%), head (9%), neck (8%) and trunk (4%; table 2). It was more common to sustain an injury in the upper (76) than in the lower (30) extremity when falling off the trampoline ($p<0.001$). In the second case, most patients were injured on the mat. Three of the hospitalised patients had an injury of the neck while performing a somersault.

Table 1 Main cause of injury

	Number (%)
Awkward landing on the trampoline	292 (53)
Fall off the trampoline	122 (22)
Collision with another person	73 (13)
Performing a somersault	59 (11)
Other	5 (1)
Unknown	5 (1)
Total	551 (100)

A ligament injury of the ankle was the most often reported diagnosis (20%), followed by an overstretching of ligaments in the neck (8%) and a fracture of the elbow (7%).

We observed significantly more fractures and dislocations in the upper than in the lower extremity ($p<0.001$). Soft tissue injury accounted for almost 30% of injuries in the upper extremity compared with 74% of injuries in the lower extremity ($p<0.001$). Of the patients, 46 (8%) had a cervical injury, of which 43 were minor overstretching of ligaments, 2 were cervical fractures, and 1 was an atlantoaxial subluxation without injury to the spinal cord. Of the patients, 49 (9%) had an injury to the head area, of which 28 were lacerations and 20 were scalp contusions. None of them were assigned a Glasgow Coma Scale score <15.[6] One patient had a fracture of the nose.

A total of 63 of 556 (11%) patients had a severe injury, as defined by an AIS value >3. Patients injured on the mat had a relative risk of 0.07 of a severe injury compared with 0.29 if falling off the trampoline. A total of 70 (13%) patients were hospitalised for a mean of 2.2 (range 1–8) days. The most common site of injury among the hospitalised patients was the elbow (27/70) followed by a fracture of the forearm (14/70).

In total, 23 patients sustained a supracondylar fracture of the humerus, and 3 of these patients reported an ulnar nerve neuropathy in association with the fracture. Two patients with displaced fractures had immediate numbness in the ulnar nerve distribution after the injury. However, they recovered after open reduction and exploration of the nerve. The third patient experienced ulnar neuropathy symptoms after a supracondylar fracture treated with closed reduction and pinning. The patient recovered after 3 months, and no exploration of the nerve was performed. None of the four patients with elbow dislocations reported a nerve injury, but one patient sustained an injury to the brachial artery. The artery was repaired with a vein graft. Two patients with

Table 2 Location of injury

	Number (%)
Head	49 (9)
Neck	46 (8)
Trunk/back	24 (4)
Shoulder	8 (1)
Upper arm	8 (1)
Elbow	62 (11)
Forearm	36 (7)
Wrist/hand	77 (14)
Hip/thigh	10 (2)
Knee	49 (9)
Leg	15 (3)
Ankle	141 (25)
Foot	31 (6)
Total	556 (100)

supracondylar fractures had diminished radial pulse immediately after the accident; however, angiography was normal. Three of the hospitalised patients had an injury of the neck while performing a somersault.

DISCUSSION

In our study, most of the injuries occurred on the body of the trampoline. Injuries were more likely with more than two people on the trampoline at the same time. The most common types of injuries were fractures, especially in children <10 years.

Several safety guidelines have been reported in the literature to reduce the incidence of trampoline-related injuries. As early as in 1977, the American Academy of Pediatrics published a position paper on trampoline injuries.[7–9] The statement recommended that the use of trampolines should be banned from physical education programmes at all school levels and that trampolining should be abolished as a competitive sport. The American Academy of Orthopaedic Surgeons[10 11] recommended that competent adult supervision and instruction are needed, and that only one participant should use the trampoline at a time. Most of the trampolines sold in Norway have a warning label with safety suggestions from the US Consumer Product Safety Commission. In addition to the above guidelines, they state that no child aged <6 years should use the trampoline, and that the trampoline should not be placed in play areas.[12]

Several publications have drawn attention to neurological injuries after use of trampolines. A recently published review found that trampoline use, boxing, American football and ice hockey are associated with alarming rates of injury to the central nervous system.[13] Brown and Lee[4] stated that injuries to the cervical spine are the leading causes of neurological injury associated with trampolines. In our study, injuries to the head and neck were the second most common injury category after injuries to the extremities, representing 17% of the injured patients. In all, 8% of the patients sustained an injury to the neck. Most of the injuries to the neck were overstretching of ligaments. However, two patients sustained a cervical spine fracture and one patient had an atlanto-axial subluxation. None of these patients sustained permanent neurological injuries. In our study, 11% of the jumpers were injured when they attempted a somersault. Many reports have emphasised that high-risk manoeuvres, such as somersaults and back flips, are not to be recommended, not even for highly skilled users.[1–4 14 15] Silver *et al*[14] reported 16 patients injured on trampolines who had severe paralysis caused by trauma to the lower cervical spine. They reported that failure of adequate supervision and the inherent power of trampolines to propel an individual as high as 9 m into the air were major contributing factors. Our findings are based on injuries in the general population, and they are comparable to those in studies with similar populations. Larson and Davis[16] concluded that recreational trampoline users perform less difficult manoeuvres and are at less risk of sustaining severe neurological injuries. The results of our survey show that serious injuries to the neck also occur on backyard trampolines.

As in other studies, we found that fractures were the predominant injury, representing 36% of all injuries.[2 16–18] Despite the recommendations that jumping on trampolines should be limited to older children, very young children are increasingly sustaining trampoline injuries.[17] They are at greater risk because of immature judgement, coordination and strength, and because of anatomical characteristics, such as open bone physes. In our study, we found a significantly higher incidence of fractures among the youngest patients who were injured compared with the older patients. Children <10 years of age were disproportionately represented among those with an AIS score >3.

Most of our patients with fractures were treated in the outpatient department. Only 13% of the patients were admitted to hospital. This is a lower proportion than reported by Furnival *et al*.[2] In our hospital, all children with fractures requiring a reduction were hospitalised.

The elbow area is commonly injured on the trampoline. In our study, four patients sustained a dislocation of the elbow after falling from the trampoline. The most common fractures were supracondylar fractures of the distal humerus. These fractures are associated with nerve injury in at least 7% of cases.[19] The ulnar nerve is particularly at risk because of its superficial location. Maclin *et al*[20] reported three cases of ulnar nerve injury sustained in children with trampoline-associated injuries. In our study, three patients reported ulnar nerve neuropathy in association with injury to the elbow. All were <10 years of age. Two of them had a supracondylar fracture of the humerus, and the third sustained a proximal fracture of the radius and ulna. Two of the patients were treated with open reduction and exploration of the nerve. In the last case, we followed up the patient with evaluation similar to Maclin *et al*.[20] All three patients improved within 4 months of the injury.

In a report from a nationwide database in New Zealand, with 2098 hospital admissions during a 10-year period, Chalmers *et al*[21] found that 80% of trampoline injuries occurred from falls off the trampoline, whereas in reports by Furnival *et al*[2] and Larson and Davis, [16] this figure was 28%. The results from Furnival *et al* are more consistent with our result, where 22% of the patients had fallen off the trampoline. In our study, a large proportion of the patients who were injured by falling off the trampoline were ⩽10 years. Some reports mention several preventive measures to reduce the risk of falling from the trampoline.[9 10 22] These included a trampoline mat of adequate size, placing the trampoline in a pit so that the mat is level with the ground and providing an energy-absorbing surface around the trampoline. In recent years, a security net around the trampoline has been recommended.[22] No data are available to show that these measures really prevent jumpers from falling off the trampoline. We only have information from 224 of our patients with regard to preventive measures. Only 15 reported the use of a security net around the trampoline. The number of jumpers who used a security net but did not have an injury is not known. We therefore cannot comment on the efficacy of this preventive measure.

Many authors have considered the centre of the mat as the most dangerous place on the trampoline. Injuries sustained on the trampoline mat occurred in half of our patients, as in other studies.[3 17] If we also include those patients who collided with another jumper, fell on to the frame and spring, or attempted a flip, up to 76% of the injuries occurred on the trampoline. The recommended safety measures would probably not have prevented these injuries. Black and Amadeo[18] emphasised the importance of multiple jumpers as a risk factor for injuries on the mat. Half of the children in their study recalled multiple jumpers on the trampoline at the time of injury. Almost 74% of our patients were injured while others were on the trampoline. Participants are at risk of colliding with other jumpers or being pushed or bounced off the trampoline. Several participants on the trampoline particularly represent a hazard for smaller children, who may be injured by the elastic recoil generated by a larger person jumping on the mat.

Although most patients in our study were injured on the mat, there was a tendency for the most serious injuries to occur after falling off the trampoline. More patients falling off the mat gained an AIS score of 3 and 4 compared with the patients who hit the mat of the trampoline.

What is already known on this topic

- Trampolines have become popular during recent years, and the number of injuries has increased with the popularity.
- Several publications have called attention to neurological injuries after use of trampolines.
- Several safety guidelines have been reported in the literature to reduce the incidence of trampoline-related injuries.

What this study adds

- Trampolining can cause serious injuries in small children's neck and elbow area.
- Serious injuries occur after falling off the trampoline.
- The use of a trampoline is a high risk activity.

Several reports on trampoline injuries recommend a ban on private, recreational trampoline use for children.[3 4 17 23] We do not, for several reasons, support such a ban. Jumping on a trampoline gives children the ability to improve their motor control. It may also increase physical activity. The risk of being injured during physical activity must be compared with the risk of being physically inactive. Being physically inactive is associated with many diseases and disorders, and in our view probably represents a greater hazard to children's health. On the other hand, it is important to be aware of the risks associated with the use of trampolines.

The fact that we cannot make any conclusions about the hazard of trampolining compared with other activities is a limitation of this study. We do not have data on time at risk for this activity, and it is therefore difficult to compare the risk of trampolining with, for example, ball sports and bicycling. Data from this study are both retrospective and prospective. Regarding the retrospective data, it is a possibility that the patients may have recalled wrong information owing to the time lapse from the actual incident.

CONCLUSION

Our study shows that trampolining can cause serious injuries, especially to the neck and elbow area in small children. It is difficult to avoid the injuries that occur on the mat. We agree with the guidelines from American Academy of Orthopaedic Surgeons,[10] which state children should not use trampolines without adult supervision. Somersaults and high-risk manoeuvres should be avoided. The supporting bars, strings and surrounding landing surfaces should have protective padding. In addition, it is important that young children should not use trampolines. The children and their parents should receive information on the potential dangers of trampoline use. Only one participant should use the trampoline at a time. It is important to prevent the jumpers from falling off the trampoline. Although our study was not designed to test the efficacy of a security net, in the absence of data to the contrary, we support the use of a security net. Our study emphasises that the trampoline is a potentially dangerous piece of athletic equipment and that it should be used sensibly.

ACKNOWLEDGEMENTS

We thank Vilhjalmur Finsen for assistance with preparation of the manuscript.

Authors' affiliations

M Nysted, J O Drogset, St Olavs Hospital, Trondheim University Hospital, Trondheim, Norway

Competing interests: None declared.

REFERENCES

1 **Smith GA**. Injuries to children in the United States related to trampolines, 1990–1995. *Pediatrics* 1998;**101**:406–12.
2 **Furnival RA**, Street KA, Schunk JE. Too many trampoline injuries. *Pediatrics* 1999;**103**:1020–5.
3 **Woodward GA**, Furnival R, Schunk JE. Trampolines revisited: a review of 114 pediatric recreational trampoline injuries. *Pediatrics* 1992;**89**:849–54.
4 **Brown PG**, Lee M. Trampoline injuries of the cervical spine. *Pediatr Neurosurg* 2000;**32**:170–5.
5 **Norim H**, Krafft M, Korner J, *et al*. Injury severity assessment for car occupants in frontal impacts using disability scaling. *J Clin Epidemiol* 1997;**50**:95–103.
6 **Cho DY**, Wang YC. Comparison of the APACHE III, APACHE II and Glascow Coma Scale in acute head injury for prediction of mortality and functional outcome. *Intens Care Med* 1997;**23**:77–84.
7 **American Academy of Pediatrics**. Committee on Accident and Poison Prevention: *Policy statement: trampolines*. Evanston, IL: American Academy of Pediatrics, 1977.
8 **American Academy of Pediatrics**. Committee on Accident and Poison Prevention and Committee on Pediatric Aspects of Physical Fitness, Recreation and Sports. Trampoline II. *Pediatrics* 1982;**67**:438.
9 **American Academy of Pediatrics**. Trampolines at home, schools, and recreational centres. *Pediatrics* 1999;**103**:1053–6.
10 **American Association of Orthopaedic Surgeons**. Trampolines and trampoline safety Document # 1135, 1999, revised 2005. (accessed 24 Oct 2006).
11 **American Association of Orthopaedic Surgeons**. Unsupervised trampoline use contributes to jump in children's injuries: orthopaedic surgeons offer tips to avoid trampoline dangers, 2005. (accessed 24 Oct 2006).
12 **United State Consumer Product Safety Commission**. Trampoline safety alert. Consumer Product Safety Document #5116. www.cpsc.gov.
13 **Toth C**, McNeill S, Feasby T. Central nervous system injuries in sport and recreation, a systematic review. *Sports Med* 2005;**35**:685–715.
14 **Silver JR**, Silver DD, Godfrey JJ. Trampolining injuries of the spine. *Injury* 1986;**17**:117–24.
15 **Hume PA**, Chalmers DJ, Wilson BD. Trampoline injury in New Zealand: emergency care. *Br J Sports Med* 1996;**30**:327–30.
16 **Larson BJ**, Davis JW. Trampoline-related injuries. *J Bone Joint Surg Am* 1995;**77**:1174–8.
17 **Smith GA**, Shields BJ. Trampoline-related injuries to children. *Arch Pediatr Adolesc Med* 1998;**152**:694–9.
18 **Black BG**, Amadeo R. Orthopedic injuries associated with backyard trampoline use in children. *Can J Surg* 2003;**46**:199–201.
19 **Beaty JH**, Kasser JR. Supracondylar fractures of the distal humerus. In: Rockwood CA, Wilkins KE, eds. *Fractures in children*. Philadelphia: Lippincott Williams and Wilkins, 2001:577–621.
20 **Maclin MM**, Novak C, Mackinnon SE. Ulnar nerve injury associated with trampoline injuries. *South Med J* 2004;**97**:720–3.
21 **Chalmers DJ**, Hume PA, Wilson BD. Trampolines in New Zealand: a decade of injuries. *Br J Sports Med* 1994;**28**:234–8.
22 **Esposito PW**. Trampoline injuries. *Clin Orthop* 2003;**1**:43–52.
23 **Hammer A**, Scwartzbach AL, Paulev PE. Some riskfactors in trampolining illustrated by six serious injuries. *Br J Sports Med* 1982;**16**:27–33.

COMMENTARY

This study deals with the risk of trampoline injuries. The trampoline is a dangerous toy. It is in fact so dangerous that some researchers have recommended a ban. The authors of the present study do not—despite a large number of injuries, some of which were serious—recommend a ban, but state that the trampoline is dangerous and should be used sensibly. They also discuss preventive measures, and suggest a few safety guidelines. It is, however, unclear whether any such guidelines are useful or not, in other words, whether they have the potential to reduce the number of injuries. This issue needs further investigation. The study clearly shows how dangerous the trampoline is, information that should be taken seriously.

J Karlsson
Sahlgrenska University Hospital/Östra, Göteborg, Sweden;
jon.karlsson@vgregion.se