# Multi-Person Trampoline Use:

## Predicting Injuries in Children

**Wilkinson A, Paterson B, Bogacz A, Drew T**

Orthopaedic and Trauma Surgery, TORT Centre, Ninewells Hospital and Medical School, University of Dundee, Scotland, UK

## Introduction

The popularity of privately-owned recreational trampolines has soared over recent years, resulting in a corresponding increase in children presenting to Accident and Emergency departments with trampoline-related injuries. Children's carers frequently fail to implement safety guidelines relating to trampoline use despite evidence to suggest that this can endanger users [1].

Multi-person trampoline bouncing is one of the most frequently reported situations at the time of injury and has commonly been observed in 64% to 83% of cases [2-5]. Bouncing with more than one person is particularly dangerous for smaller users due to large, difficult to predict energy transfers which can occur between users, passing from larger to smaller subjects.

If the physiological limits of children's lower limbs are considered it is not surprising that lower limb injuries are frequently reported [6-8]. Fractures are commonly reported in children due to the relative weakness of the epiphysis of long bones compared with other supportive structures around joints.

## Aim

This study aims to highlight the dangers of multi-person trampolining using a computational model which simulates trampoline bouncing.

## Methods and Materials

A trampoline model was created using Autodesk Inventor 11 Dynamic Simulation. The model allowed analysis of the vertical forces and rate of loading which can be experienced by users and was capable of replicating the large transfers of energy which can occur when more than one person bounces on a trampoline.

Trampoline use with between one and three bouncers and variations in differences of mass between users was compared.

Figure 1. is an illustration of the model with a graph of the vertical forces exerted on the masses during contact with the trampoline mat.

The model was validated by measuring the mat stiffness of actual privately owned trampolines using static loads of up to 40kg.

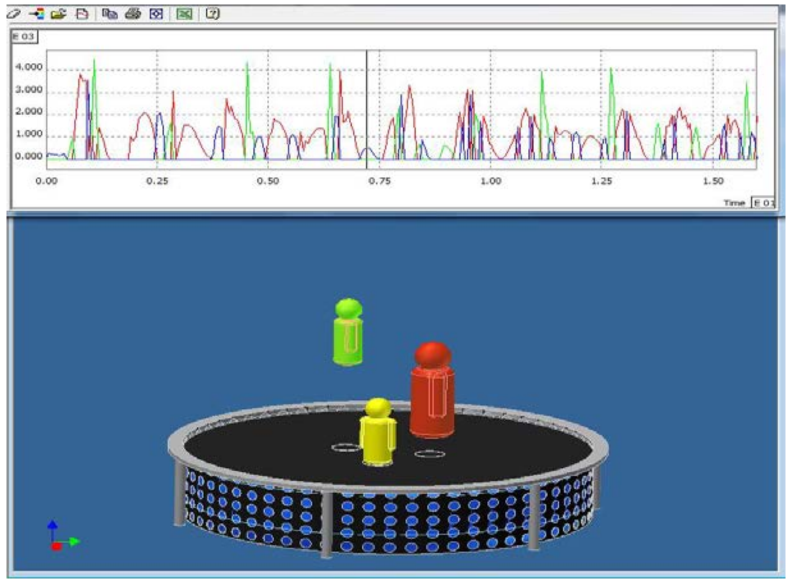

Figure 1. Autodesk Inventor biomechanical model. The line colour in the graph corresponds with the colour of the mass (except for the blue line which represents the yellow mass).

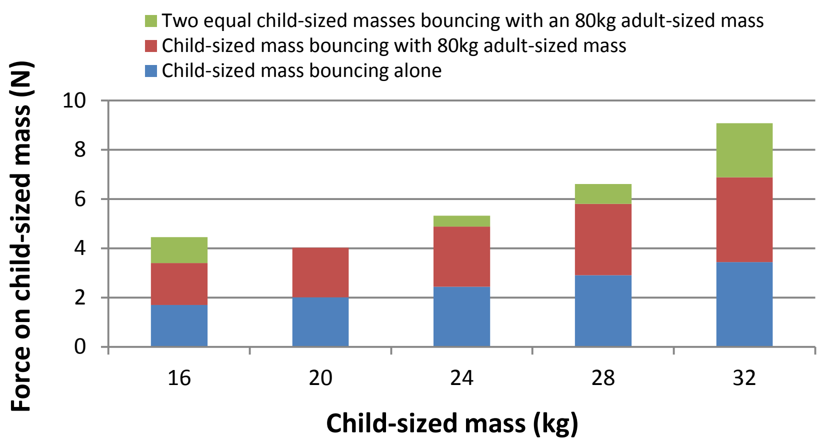


Figure 2. Comparison of maximum forces exerted on child-sized mass during one, two and three person bouncing

Table 1. Maximal fall heights experienced by child-sized masses during bouncing.

| Approximate age of the child-sized mass (Mass) | 4 years (16kg) | 6 years (20kg) | 8 years (24kg) | 10 years (28kg) | 12 years (32kg) |
|---|---|---|---|---|---|
| Masses of other users | 80kg 16kg | 80kg 20kg | 80kg 24kg | 80kg 28kg | 80kg 32kg |
| Equivalent fall height | 4.4m | 3.7m | 3.2m | 4.5m | 3.5m |

## Results

Preliminary results have suggested that compared with bouncing alone, small child-sized masses were subjected to extremely high loads and rates of loading when bouncing with other users.

The high forces experienced by the smallest masses occurred mainly in two situations. The smallest mass was either landing after a high jump following an energy transfer, or landing just after or during the largest mass leaving the mat, which was recoiling.

A mass of 16kg, which is approximately equivalent to the mass of a 4 year old can be subjected to over double the loading force when bouncing with two other masses compared with bouncing alone. This is illustrated in Figure 2.

When smaller masses experienced energy transfers from larger users their maximal height reached up to 4.5m above the trampoline mat, for a mass of 28kg. See Table 1. for maximal fall heights for other child-sized masses.

Due to the unpredictability of the energy transfers it is not always possible to observe large energy transfers for every input scenario. This was the case for the 20kg mass, where three person bouncing was not observed to result in higher forces compared with two person bouncing.

## Conclusion

This model highlights the dangers of children bouncing with other users. Using maximal fall heights enables easy interpretation of potential forces which children could be subjected to, during trampoline use. It is interesting that smaller masses are more likely to be subjected to large energy transfers when bouncing with two others masses. This situation is likely to be commonly encountered in private trampoline use when several children bounce together.

The magnitude of the forces and rates of loading exerted on the child-sized masses is concerning when considering the physiological limits of bones and ligaments in children.

In the future, comparison of loading forces during trampolining, as illustrated in this model, and known physiological limits of epiphyses in children, may allow for the prediction of injuries in situations of multi-person trampoline use.

References: [1] (2006) Trampolines: Trampoline safety factsheet - The Royal Society for the Prevention of Accidents. [2] Wootton M, Harris D (2009) Trampoline injuries presenting to a children's emergency department. Emerg Med J; 26: 728-731. [3] Eberl R, Schalamon J, Singer G, Huber S S, Spitzer P & Hollwarth M E (2009) Trampoline-related injuries in childhood. Eur J Pediatr; 168: 1171-4. [4] Nysted M, Drogset J O (2006). Trampoline injuries. Br J Sports Med; 40: 984-7. [5] McDermott C, Quinlan J F, Kelly I P (2006) Trampoline injuries in children. J Bone Joint Surg Br; 88: 796-8. [6] Shankar A, Williams K, Ryan M (2006) Trampoline-related Injury in Children. Pediatric Emergency Care; 22; 9: 644-646. [7] Bogacz A, Paterson B, Babber A, Menelaws S, Drew T (2009). Trampoline injuries. How to avoid injury. BMJ, 338, b2197. [8] American Academy of Pediatrics (2006) Trampolines at Home, School and Recreational Centres. Pediatrics; 103; 5: 1053-1056