



The anterior tilt angle of the proximal tibia epiphyseal plate: A significant radiological finding in young children with trampoline fractures



Enno Stranzinger^{a,*}, Lars Leidolt^{a,1}, Georg Eich^{b,2}, Peter Michael Klimek^{c,3}

^a University Hospital Bern, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, CH-3010 Bern, Switzerland

^b Cantonal Hospital Aarau, Pediatric Radiology, Tellstrasse, CH-5001 Aarau, Switzerland

^c Cantonal Hospital Aarau, Pediatric Surgery, Tellstrasse, CH-5001 Aarau, Switzerland

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ABSTRACT

Objective: Evaluation of the anterior tilt angle of the proximal tibia epiphyseal plate in young children, which suffered a trampoline fracture in comparison with a normal population.

Materials and methods: 62 children (31 females, 31 males) between 2 and 5 years of age (average 2 years 11 months, standard deviation 11 months) with radiographs in two views of the tibia were included in this retrospective study. 25 children with proximal tibia fractures were injured with a history of jumping on a trampoline. All other causes for tibia fractures were excluded. A normal age-mapped control cohort of 37 children was compared. These children had neither evidence of a trampoline related injury nor a fracture of the tibia. The anterior tilt angle of the epiphyseal plate of the tibia was defined as an angle between the proximal tibia physis and the distal tibia physis on a lateral view. Two radiologists evaluated all radiographs for fractures and measured the anterior tilt angle in consensus. An unpaired Student's *t*-test was used for statistical analysis (SPSS). Original reports were reviewed and compared with the radiological findings and follow-up radiographs.

Results: In the normal control group, the average anterior tilt angle measured -3.2° , $SD \pm 2.8^\circ$. The children with trampoline fractures showed an anterior tilt of $+4.4^\circ$, $SD \pm 2.9^\circ$. The difference was statistically significant, $P < 0.0001$. In 6 patients (24% of all patients with confirmed fractures) the original report missed to diagnose the proximal tibial fracture.

Conclusion: Young children between 2 and 5 years of age are at risk for proximal tibia fractures while jumping on a trampoline. These fractures may be very subtle and difficult to detect on initial radiographs. Measurement of the anterior tilt angle of the proximal tibia epiphyseal plate on lateral radiographs is supportive for interpreting correctly trampoline fractures.

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1. Introduction

Trampoline injuries in children are steadily increasing [1–3]. Boyer et al. observed in the 1980s over a period of 4 years 7 children with trampoline fractures in a tertiary care hospital [4]. In the last 5 years we observed 25 trampoline fractures. Children 2–5 years

of age are particularly at risk for a “trampoline fracture” [5]. This fracture may occur by bouncing repeatedly on the trampoline, especially if the infant jumps together with older or heavier children. There is usually no specific traumatic event identified. The knee joint hyperextends and excessive axial compression to the proximal tibia occurs [1,3,4,6,7]. This mechanism leads to this classic trampoline fracture, since the bone of young infants and toddlers is relatively soft and less resistant to axial forces [2–4,8]. Radiological signs of a trampoline fracture may be a buckle or torus fracture or a transverse hairline fracture of the proximal tibia metaphysis. A scooping of the notch for the tibial tubercle and subtle buckling of the anterior cortex of the upper tibia is typically noted [5]. An anterior tilting of the proximal tibia epiphyseal plate epiphysis is an important finding [3,4,6,7,9,8,10]. In clinical routine a trampoline fracture however may be subtle and difficult to depict. The aim

* Corresponding author. Tel.: +41 031 632 9504; fax: +41 031 632 9664.

E-mail addresses: enno.stranzinger@insel.ch (E. Stranzinger),

lars.leidolt@insel.ch (L. Leidolt), georg.eich@ksa.ch (G. Eich), peter.klimek@ksa.ch (P.M. Klimek).

¹ Tel.: +41 031 632 9504; fax: +41 031 632 9664.

² Tel.: +41 062 838 52 13; fax: +41 062 838 54 92.

³ Tel.: +41 062 838 48 97; fax: +41 062 838 54 92.

of this study is to determine the anterior tilting of a normal population between 2 and 5 years of age and to compare this finding with young children which suffered a trampoline fracture.

2. Materials and methods

The hospital ethics committees of the two hospitals involved approved this retrospective study. Sixty-two patients were included in this study (31 females, 31 males, average 2 years 12 months, standard deviation 11 months). A tertiary pediatric university hospital ($n = 50$ patients) and a large non-university hospital with a dedicated pediatric radiologist and pediatric surgeons ($n = 12$ patients) were involved in this study. Subjects were identified by a radiology information system (Centricity RIS 4.2. Plus, General Electric Company, Barrington, USA) search of children 2–5 years of age between January 2007 and August 2013 with radiographs of the tibia in two views.

For the normal population ($n = 37$, 22 males, 15 females, average age 3 years and 1 month, standard deviation 12 months) inclusion criteria were absent history of trampoline injuries and axial trauma to the tibia. The population with trampoline fractures ($n = 25$, 9 males, 16 female, average age 3 years, standard deviation 10 months) had a history of a trampoline related injury and a proximal tibia fracture. Criteria for a trampoline fracture were a visible hairline or torus fracture of the proximal tibia metaphysis, or anterior buckling of the tibial cortex, or an anterior scooping of the notch for the tibial tubercle, or anterior tilting of the tibia epiphyseal plate. All original reports and all follow-up radiographs were reviewed when available.

Two radiologists, a pediatric radiology staff with 13 years and a radiology resident with 4 years of experience evaluated all radiographs of the tibia in two views in consensus. All original reports were reviewed.

The anterior tilt angle of the tibia was measured on a lateral radiograph including the proximal and distal tibial epiphyseal plate (Fig. 1). The proximal line of the angle was defined by drawing a tangent between the dorsal- and mid-point of the physis (the anterior point of the physis may be used if the line intersects also the mid-point). The distal line of the angle was defined by drawing a tangent between the dorsal and ventral epiphyseal plate of the distal physis (Fig. 1). Measurements for the study were made with the angle measurement tool on a picture archiving and communication system (Sectra PACS IDS7™, Linköping, Sweden).

The unpaired Student's *t*-test was used for statistical analysis to compare the anterior tilt angle between the group without fractures and the group with trampoline fractures. The software IBM SPSS Statistics (Version 21, IBM Armonk, USA) was used to compute the analysis. *P* value less than 0.05 were considered significant.

3. Results

Trampoline fractures ($n = 25$) were most prevalent in the 2-year-old children ($n = 14$, 56%), followed by the 3-year-old children ($n = 6$, 24%). Children 5 years of age showed less often a proximal tibia fracture ($n = 1$, 4%) (Fig. 2).

The average anterior tilt angle in the normal population ($n = 37$) was -3.2° with a standard deviation of $\pm 2.8^\circ$. In the group of children with tibia fractures ($n = 25$), the anterior tilt angle measured $+4.4^\circ$ with a standard deviation of $\pm 2.9^\circ$ (Fig. 3). The statistical analysis showed a significant difference of the anterior tilt angle in these two groups, $P < 0.0001$ (Fig. 4).

Significant differences of the anterior tilt angle were found between the group with trampoline fractures and the normal cohort in every single age group (2, 3, 4 and 5 year old). There were no age- or sex-related differences found.



Fig. 1. Two-year-old girl with a normal left tibia on two views. The anterior tilt angle measures -4.5° . The line drawing shows the measurement of the tibial tilt through the proximal and distal epiphyseal plates.

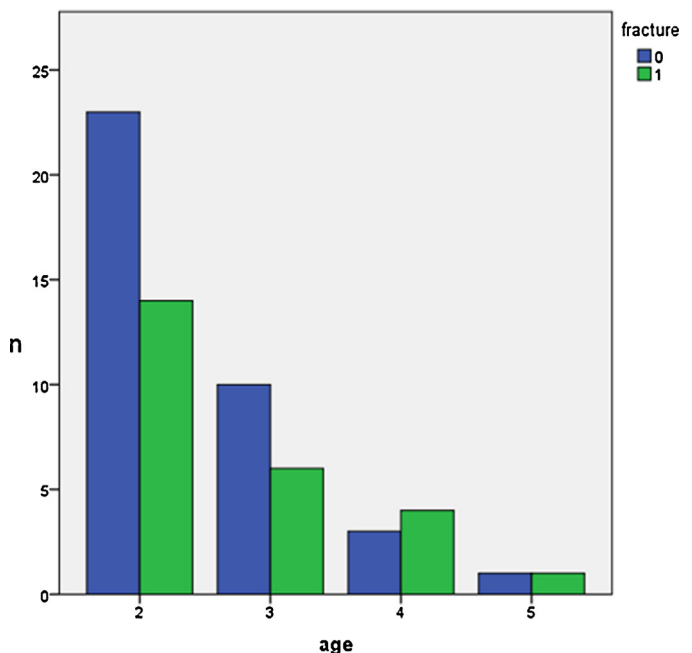


Fig. 2. Age distribution of the patients with trampoline fractures (1) and without fractures (0). Most trampoline fractures were noted within the age group of two and three year old children. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

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