

Epiphyseal stress fractures in the fingers of adolescents: Biomchanics, Pathomechanism, Risk factors, and Ultrasound

Dr.med., Dr.rer.biol.hum., Dipl. Biol., MSc. Isabelle Schöffl, Kinderklinik Bamberg, Sportmedizin Bamberg,

Kaimsgasse 30, 96052 Bamberg, isabelle.schoeffl@me.com

Dr. med. Michael Simon, Sportmedizin Bamberg, Buger Str. 80, 96049 Bamberg

info@michaelsimon.org

Dr. med. Christoph Lutter, MHBA Sportmedizin Bamberg, Buger Str. 80, 96049 Bamberg

Christoph.lutter@googlemail.com

Prof. Dr.med. Volker Schöffl, MHBA Sportmedizin Bamberg, Kaimsgasse 30, 96052 Bamberg

Volker.schoeffl@me.com

Abstract:

Epiphyseal growth plate injuries have increased over the last years and can lead to permanent damage of the finger. We developed a biomechanical approach to explain the causes leading to this injury.

For evaluating our theoretical approach, we designed a questionnaire examining the circumstances leading to the injury as well as the training routines of eighteen injured adolescents. In a second approach we undertook an ultrasound examination of fingers with a proven growth plate fracture of the finger. Of the 22 injured fingers, 95% concerned the middle finger; in 64.3% the crimp grip led to the injury and was the preferred handhold (71.4%). Half of the injuries occurred during bouldering competitions. 81% of the injuries were Salter Harris grade 3, only two were grade 1 and 5 respectively. With rest all adolescents regained full finger function, one athlete remains with a permanent finger damage. Most of the injured adolescents were male (75%). They were in average 14.1 years of age and all within the year of their peak velocity growth. Ultrasound examination proved to be a valuable tool for determining this injury. Adolescent climbers thus are at a high risk for epiphyseal fractures especially during their growth spurt.

Concept

Les lésions de la plaque de croissance épiphysiale ont augmenté au cours des dernières années et peuvent occasionner des dégâts irréversibles dans le doigt concerné. Nous avons pensé aborder le sujet sur le plan biomédical, dans le but d'expliquer les causes de ces lésions. Afin d'évaluer notre approche théorique, nous avons établi un questionnaire portant sur les différentes causes qui ont mené à ces blessures ainsi que les routines établies pendant les séances d'entraînement. Puis, nous avons examiné ces doigts par ultra-sons avec une plaque de croissance éprouvée. Nos études ont porté sur 22 doigts. Dans 95% des cas, il s'agissait du majeur, chez 64%, la lésion provenait de la prise d'éclatement (??) et c'était la meilleure position de la main. (71%). La moitié de ces lésions se sont produites pendant des compétitions de bloc. 81% étaient des "Salter Harris" de niveau 3, seules deux lésions concernaient respectivement le niveau 1 et 5. Après une période de repos, presque tous les adolescents ont retrouvé une parfaite mobilité de leurs doigts, un seul athlète conservera des séquelles. La plupart des adolescents étaient de sexe masculin, (75%), leur âge moyen était de 14,1 ans et tous étaient en pleine période de croissance. Les examens aux ultra-sons ont été de grande utilité afin d'expliquer ce genre de lésion, ce qui nous autorise à conclure que chez les grimpeurs adolescents, il existe un grand risque concernant les fractures épiphysaires, spécialement pendant la période de croissance.

Introduction

Fractures to the epiphyseal plates of adolescent climbers are relatively new pathologies that had so far not been seen before in this sport (T. Hochholzer & Schöffl, 2005), but have been observed in other sports such as baseball (Carson & Gasser, 1998; Dotter, 1953; Rettig, Wurth, & Mieling, 2006), and gymnastics (Carter, Aldridge, Fitzgerald, & Davies, 1988; Read, 1981; Roy, Caine, & Singer, 1985). The main cause for this injury seems to be repetitive stress. The climbing community only started reporting epiphyseal stress fractures in the fingers in 1997 (T. Hochholzer, Schöffl, & Krause, 1997) and in 1999 (Chell, Stevens, Preston, & Davis, 1999). As a consequence of repetitive loading of the fingers the fractures observed were always in the proximal interphalangeal joint (T. Hochholzer et al., 1997). Most often they were fractures of the Salter Harris III type with a fracture through the epiphysis of the middle phalanx (T. Hochholzer, Schöffl, & Bischof, 2002). Within a short period of time (24 years) a total of 65 epiphyseal fractures of the fingers have been reported in climbers representing the highest rate of this injury so far in any sport (Chell et al., 1999; T. Hochholzer, Straub, G., Schöffl, V., Bayer, T., 2013).

Most injuries heal with rest and the athletes are able to return to their sport most often reaching their previous level easily. However with regard to every typical injury there are reports of either premature closure of the physis (Bak & Boeckstyns, 1997; Carson & Gasser, 1998; Laor, Wall, & Vu, 2006), or deformities as a consequence of asymmetric epiphyseal injuries that did not heal (Bak & Boeckstyns, 1997; Laor et al., 2006). The purpose of this study was to develop a theoretical model for the biomechanic cause of this pathology. Furthermore, we wanted to determine the pathomechanism, and risk factors leading to this injury using a questionnaire in a group of injured adolescents and evaluate our theoretical model.

Material and Methods

We collected the data of 18 adolescent climbers with epiphyseal fractures over the period of five years between 2009 and 2013. We obtained plain radiographs on every injured finger as well as magnetic resonance imaging. Biometric data (age, gender) were obtained and a detailed questionnaire was distributed among the athletes. The questionnaire focused on determining the moment of the growth spurt and training specifics as well as climbing specialties. In a second study, we performed ultrasound examinations of 5 athletes with proven growth plate fractures.

Results

Over five years 18 adolescents presented themselves with 22 epiphyseal fractures. The middle finger was concerned in 95%. When the injury occurred nine patients (64.3%) were holding on to a crimp, and two (7.1%) had a hanging finger position. The crimp grip position was the favorite grip form (71.4%). The injury occurred mainly during bouldering in 7 (50%),.. Most (71.4%) of the subjects said that they had warmed up properly before having the injury, only one (5.6%) could remember injuring himself while warming up.

Eighteen fractures were Salter Harris grade 3 (81.8%), two were grade 1 (9.1%) and two were grade 5. However, the two fractures with grade five occurred in the same climber. Considering the outcome 69.2 % (9 out of 13) had a very good outcome with the complete return of the finger function as before. However, one patient could not recover full finger function in the two affected middle fingers with swelling around the joints and movement impairment.

Of these 18 adolescents 14 were male (75%) and 4 female (25%). They were 14.1 years old in average. In average, they had grown 7.2 cm (std 1.6 cm) in the past year and when investigating their growth curves, they were all growing at the peak velocity of their respective growth curves. They were growing below the 50th

percentile by 0.77 cm (std. 6.6 cm) and were 6.6 kg lighter, their BMI was thus 1,6 kg/m² below the 50th percentile. Their first signs of puberty had appeared 14.4 (std. 12.26) months prior to the injury.

At the time of the injury the subjects had been training 8.2 (std 3.4) hours of training per week. This training consisted mostly of climbing and bouldering, with a little bit of strengthening exercises with. Only a few had done campus board training at the time. They were climbing an average level of 8.9 (std 0.6) on the UIAA metric scale (Schoffl, Morrison, Hefti, Ullrich, & Kupper).

After diagnosis of an epiphyseal fracture our team suggests 6 – 8 weeks of rest before coming back for a control MRI. As a consequence, the subjects in this study started climbing again after a mean of 6.8 weeks and regained their previous level of climbing within 3 months. The only exception was the athlete who did not regain full finger function, as the fractures were already more than a year old when he came to see us. Rest and rehabilitation did not improve or change the outcome.

In the ultrasound examination the lateral displacement of the bone fragment proved to be the most valuable tool for diagnosing growth plate fractures.

Discussion

When analyzing the results of this study one of the most worrying findings was the sheer number of adolescents who had injured themselves over such a short amount of time. No other sport has had such a high frequency of epiphyseal fractures so far (Carson & Gasser, 1998; Carter et al., 1988; Laor et al., 2006).

In 95% of the cases the middle finger was the injured finger. The middle finger is the longest finger of the hand, and thus received the most strain, especially in a crimp grip position, as explained in a biomechanical model by Vigouroux et al. (Vigouroux, Quaine, Palet, Colloud, & Moutet, 2008). The crimp grip was the favored grip form and also the one that led in most cases to the reported injury.

Bouldering was the most often remembered circumstance for the injury. There have been tendencies to ban international boulder competitions in adolescents in the past (Schöffl, 2004). However, these measures cannot be held up as there are more and more local competitions, which allow kids to participate, and which are not under the surveillance of any institution. However, childhand friendly handholds which cannot easily be crimped and regulations for competitions may reduce the dangers of this injury.

Most of the fractures observed in our study were of grade Salter Harris 3 (81.2%). Only two subjects had minor fractures of grade 1 and one patient had a crush injury (Salter Harris 5) in both middle fingers. This is a consequence of the biomechanics, as in climbing the epiphysis is pushed out on the dorsal aspect of the finger when the finger is subjected to high forces in the crimp grip position.

Although the outcome was good in most of our patients, in one patient a permanent damage to both of his middle fingers occurred. The injury had been overlooked by several physicians. Knowledge and awareness are essential for treating adolescent climbers.

Over the time period of this study we saw more boys injuring their growth plates (14 out of 18) than girls (only 4 out of 18). This may have several causes. For one, climbing is still a sport which is dominated by males.

However, the growth spurt is caused by a stimulation of growth hormone production by low doses of estradiol (Ross et al., 1983). As the doses of estradiol increase, the growth is increasingly inhibited up to the fusion of the physes (Parfitt, 2002). The differences in estradiol levels during puberty may well explain the higher number of injuries in boys than in girls.

We were able to evaluate growth curves of eight of the subjects and were able to see, that all the injuries occurred around the time of the pubertal growth spurt. This confirms literature findings, which suggest that the

epiphyseal plate is exceptionally vulnerable during times of rapid growth (Bailey, McKay, Mirwald, Crocker, & Faulkner, 1999; Flachsmann, Broom, Hardy, & Moltschaniwskyj, 2000). This higher vulnerability is believed to be the consequence of the structural changes during rapid growth leading to a thicker and more fragile plate, and to the fact that bone mineralization may lag behind the linear growth, rendering the bone more porous (Bailey, Wedge, McCulloch, Martin, & Bernhardson, 1989).

When investigating the training regimen of the subjects we were pleased to note that only little training was spent on the campus board. This strenuous exercise seems to be extremely dangerous and further measures need to be taken to increase the awareness of this danger.

Ultrasound was only used on five patients but yielded promising results. Further research is needed for establishing this cheap and easily available tool for diagnosing the injury.

Literature

- Bailey, D. A., McKay, H. A., Mirwald, R. L., Crocker, P. R., & Faulkner, R. A. (1999). A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children: the university of Saskatchewan bone mineral accrual study. *J Bone Miner Res*, *14*(10), 1672-1679.
- Bailey, D. A., Wedge, J. H., McCulloch, R. G., Martin, A. D., & Bernhardson, S. C. (1989). Epidemiology of fractures of the distal end of the radius in children as associated with growth. *J Bone Joint Surg Am*, *71*(8), 1225-1231.
- Bak, K., & Boeckstyns, M. (1997). Epiphysiodesis for bilateral irregular closure of the distal radial physis in a gymnast. *Scand J Med Sci Sports*, *7*(6), 363-366.
- Carson, W. G., Jr., & Gasser, S. I. (1998). Little Leaguer's shoulder. A report of 23 cases. *Am J Sports Med*, *26*(4), 575-580.
- Carter, S. R., Aldridge, M. J., Fitzgerald, R., & Davies, A. M. (1988). Stress changes of the wrist in adolescent gymnasts. *Br J Radiol*, *61*(722), 109-112.
- Chell, J., Stevens, K., Preston, B., & Davis, T. R. (1999). Bilateral fractures of the middle phalanx of the middle finger in an adolescent climber. *Am J Sports Med*, *27*(6), 817-819.
- Dotter, W. E. (1953). Little leaguer's shoulder: a fracture of the proximal epiphysial cartilage of the humerus due to baseball pitching. *Guthrie Clin Bull*, *23*(1), 68-72.
- Flachsmann, R., Broom, N. D., Hardy, A. E., & Moltschaniwskyj, G. (2000). Why is the adolescent joint particularly susceptible to osteochondral shear fracture? *Clin Orthop Relat Res*(381), 212-221.
- Hochholzer, T., Schöffl, V., & Bischof, B. (2002). [Epiphyseal fractures of the middle phalanx in sportclimbers] Epiphysenfrakturen der Fingermittelgelenke bei Sportkletterern. *Sport Ortho Trauma*, *18*, 87-92.
- Hochholzer, T., Schöffl, V., & Krause, R. (1997). Finger-Epiphysenverletzungen jugendlicher Sportkletterer. *Sport Ortho Trauma*, *13*(2), 100-103.
- Hochholzer, T., & Schöffl, V. R. (2005). Epiphyseal fractures of the finger middle joints in young sport climbers. *Wilderness Environ Med*, *16*(3), 139-142.
- Hochholzer, T., Straub, G., Schöffl, V., Bayer, T. (2013). Knöcherne Stressreaktionen der Hand bei Jugendlichen Sportkletterern. *Alpinmedizinischer Rundbrief*, *48*, 20 - 25.
- Laor, T., Wall, E. J., & Vu, L. P. (2006). Physeal widening in the knee due to stress injury in child athletes. *AJR Am J Roentgenol*, *186*(5), 1260-1264.
- Parfitt, A. M. (2002). Misconceptions (1): epiphyseal fusion causes cessation of growth. *Bone*, *30*(2), 337-339.
- Read, M. T. (1981). Stress fractures of the distal radius in adolescent gymnasts. *Br J Sports Med*, *15*(4), 272-276.
- Rettig, A. C., Wurth, T. R., & Mieling, P. (2006). Nonunion of olecranon stress fractures in adolescent baseball pitchers: a case series of 5 athletes. *Am J Sports Med*, *34*(4), 653-656.
- Ross, J. L., Cassorla, F. G., Skerda, M. C., Valk, I. M., Loriaux, D. L., & Cutler, G. B., Jr. (1983). A preliminary study of the effect of estrogen dose on growth in Turner's syndrome. *N Engl J Med*, *309*(18), 1104-1106.
- Roy, S., Caine, D., & Singer, K. M. (1985). Stress changes of the distal radial epiphysis in young gymnasts. A report of twenty-one cases and a review of the literature. *Am J Sports Med*, *13*(5), 301-308.
- Schoffl, V., Morrison, A., Hefti, U., Ullrich, S., & Kupper, T. The UIAA Medical Commission injury classification for mountaineering and climbing sports. *Wilderness Environ Med*, *22*(1), 46-51.
- Schöffl, V., Schlegel, C. (2004). Statement International Boulder Competitions in Youths. *UIAA MedCom Recommendation*.
- Vigouroux, L., Quaine, F., Paquet, F., Colloud, F., & Moutet, F. (2008). Middle and ring fingers are more exposed to pulley rupture than index and little during sport-climbing: a biomechanical explanation. *Clin Biomech (Bristol, Avon)*, *23*(5), 562-570.