Acta orthop. scand. *54*, 634–640, 1983

CHILDREN'S ANKLE FRACTURES

Classification and Epidemiology

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In an investigation of childhood and adolescence fractures (age groups 0–16) occurring in Malmö during 1950, 1955, 1960, 1965, 1970 and 1975–79, a total of 8682 were found. Four per cent or 373 ankle fractures were classified according to their roentgenological appearance.

Avulsion fractures of the tip of the lateral malleolus were the most frequent, followed by fractures involving the distal fibular physis. Triplane and Tillaux fractures were the third and fourth most common fracture groups. Tillaux fractures were more common in girls ($0.01 > P > 0.001$). There was no statistically significant difference between the sexes in the other fracture groups or in the whole series.

Most injuries were caused by low energy trauma. A foot caught in a bicycle wheel resulted more often in an epiphyseal fracture of the lateral malleolus than any other type of fracture. Otherwise no other etiological factor caused a significant number of cases in any fracture group.

There was a seasonal variation with twice as many fractures during April and September as compared with July and December. The incidence showed a steady increase during growth which ceased after the early teens due to a lower incidence among girls in the age groups 15–16. The incidence increased significantly during the 30 years covered by this study.

Key words: adolescents; children; ankle fractures; classification; epidemiology; incidence

Accepted 3.xii.82

The mechanical properties of the growing skeleton produce fractures other than those seen in adults and in the elderly. As for ankle injuries, classification according to systems designed for adults is usually unsuccessful (Vahvanen & Aalto 1980). Various classifications of children's ankle fractures have been presented in the past (Bishop 1932, Carothers & Crenshaw 1955, Johnson & Fahl 1957, Gerner-Smidt 1963). Recently, Dias & Tachdjian (1978) presented a classification, which seems to be the most appropriate hitherto, since it is based on factors such as the position of the foot, direction of force and type of epiphyseal injury in accordance with the Salter-Harris' classification (1963).

Whenever a Salter-Harris III or IV injury is present, there is a risk of premature epiphyseal line closure with subsequent growth disturbance and deformity (Salter & Harris 1963).

The Dias & Tachdjian classification, however, is concerned only with physeal injuries. Injuries in adolescence, when the ankle growth plates are closed, are not included.

The purpose of this study was threefold: to describe the pattern of ankle fractures in childhood and adolescence by applying an extended

Financial support was obtained from Herman Järnhardt's Foundation and the Swedish Medical Research Council project No. B82-17X-02737-14.

classification based on that proposed by Dias & Tachdjian (1978); to calculate the incidence of ankle fractures in children under 16; and to reveal possible secular changes.

METHODS

More than 95 per cent of all roentgen examinations owing to trauma in the city of Malmö (population 230 000), are carried out at the Department of Radiology, Malmö General Hospital. Since 1950, all examinations have been classified according to diagnosis, and all referrals, reports and films are available. The age and sex distribution of the population of the city are recorded in census data for every 5-year period and, since 1968, as annual data. The conditions for fracture epidemiology studies are therefore favourable and have been exploited in the past (Alffram & Bauer 1962, Alffram 1964, Nilsson 1967, Horak & Nilsson 1975).

In an investigation aimed at describing the epidemiology of childhood fractures (Landin, in manuscript) information concerning all fractures in the age group 0–16 years was sampled and recorded from the years 1950, 1955, 1960, 1965, 1970 and 1975–79. Non-residents were excluded. This material consists of altogether 8682 childhood and adolescence fractures from which all ankle fractures were extracted and classified according to their roentgenological appearance. During this work it became obvious that the classification of Dias & Tachdjian was incomplete since the fibular and tibial growth plates were often partially or completely closed in the older age groups. Therefore, the classification had to be extended to include groups with a more adult fracture pattern. Also, the Tillaux and triplane types of fracture were included. This resulted in the following classification, in which the fracture groups 1–7 are the same as those outlined by Dias & Tachdjian (Figure 1).

Group 8. The Tillaux fracture was named after the French surgeon, who was among the first to draw attention to it at the end of the 19th century. It is usually described as a Salter-Harris III lesion of the antero-lateral part of the distal tibial epiphysis. It is generally agreed (Kleiger & Mankin 1964) that it is produced by a supination-outward rotation force which widens the ankle mortice, causing a traction of the anterior tibiofibular ligament and a subsequent avulsion fracture of its insertion on the distal tibial epiphysis.

Group 9. Triplane fractures. The first to describe this injury was Marmor (1970), who identified the three components – an anterior-lateral epiphyseal fragment similar to that seen in a Tillaux fracture, the remainder of the epiphysis connected with a posterior lateral metaphyseal fragment and, finally, the rest of the tibial metaphysis. Thus, there are fractures of the Salter-Harris type II, III and IV and fracture lines in three planes – sagittal through the epiphysis, transverse through the growth plate and in the frontal plane through the posterior metaphyseal region of the tibia. The triplane fracture is probably caused by a combination of plantar flexion forces and outward rotation (Dias & Tachdjian 1978). Later, others (Cooperman et al. 1978, Kärrholm et al. 1981) have described types of triplane fractures different from the one reported by Marmor (1970) and Lynn (1972), but meeting the same criteria; namely, fractures in the sagittal, transverse and frontal planes.

Groups 10 and 11 are avulsion fractures from the lateral and the medial malleolus, respectively (Broström 1966, Danielsson 1980).

Groups 12–13 consist of cases with epiphyseal lines partially or completely closed and fractures with an appearance usually seen among adults.

Group 14 is made up by combinations of fractures with adult appearance.

Group 15. Fractures not under the present classification.

RESULTS

Of the total material of 8682 fractures, 373 were ankle fractures – a frequency of 4 per cent in the age groups studied. Figure 2 shows the number of fractures in each group, frequency, sex ratio, right/left ratio and mean age. The frequency was equal for boys and girls in the whole series and all subgroups except for Tillaux fractures which were more common in girls ($P < 0.01$) than in boys.

Fractures were observed to occur more often in the right ankle ($P < 0.01$) in the whole material and this difference was also found in groups 2, 10 ($P < 0.01$) and 11 ($0.05 > P > 0.01$).

Differences in mean age were found between group 1 and the added groups 2–3 ($0.05 > P > 0.01$). By definition, groups 12–14 consist of fractures in patients with partially or completely closed growth plates, comparisons being therefore only made between groups with open epiphyseal lines caused by the same mechanism of trauma.

More than half of the patients were injured when falling, and information from the files indi-

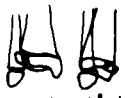
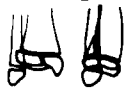
	Type	Foot position	Abnormal force	Type according to Salter-Harris	
				Fibula	Tibia
1		Supination	Inward rotation	1 or 2	-
2		Supination	Inward rotation	1 or 2	3 +(5)
3		Supination	Inward rotation	1 or 2	4 +(5)
4		Supination	Plantar flexion	-	2
5		Supination	Outward rotation	-	2
6		Supination	Outward rotation	High fracture	2
7		Pronation	Outward rotation	High fracture	2
8		Supination	Outward rotation	-	3
9		Supination	Outward rotation plantar flexion	(High fracture)	2. 3. 4.
10		Supination	Inward rotation	Tip fracture (avulsion)	-
11		Pronation	Outward rotation	-	Tip fracture (avulsion)
12		Supination	Inward rotation	Epiphyseal lines partially or completely closed	
13		Supination	Inward rotation	- " -	
14		Adult fracture pattern	Miscellaneous	- " -	
15		Fractures not under classification	Miscellaneous		

Figure 1. Fracture classification. Inward rotation – synonyms: inversion, supination, internal –, medial rotation. Outward rotation – synonyms: eversion, pronation, external–, lateral rotation.

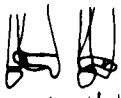
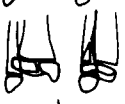
Type	Number	Per cent	Boys/Girls	Right/Left	Mean age ± SEM
1 	60	16	35/25	37/23	
2 	21	6	13/8	17/4	
3 	5	1	4/1	5/0	
4 	13	3	3/10	9/4	
5 	10	3	8/2	6/4	
6 	1		1/0	1/0	
7 	13	3	10/3	9/4	
8 	21	6	4/17	10/11	
9 	31	8	11/20	15/16	
10 	131	35	68/63	86/45	
11 	16	4	11/5	13/3	
12 	14	4	4/10	7/7	
13 	15	4	9/6	9/6	
Adult fracture pattern	12	3	6/6	5/7	
Fractures not under classification	10	3	3/7	4/6	
	373		190/183	233/140	10 11 12 13 14 15 16

Figure 2. Distribution of fractures according to type, sex, side and mean age.

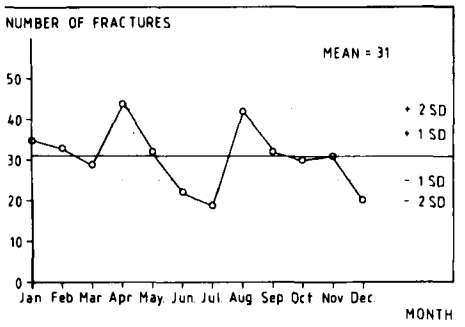


Figure 3. Seasonal variation.

cate falls from levels higher than the ground in one quarter of all fall injuries. Catching the foot in a bicycle wheel resulted more often in a type I lesion ($P < 0.001$) than in any other type. No other clearly defined circumstance contributing to a significant number of fractures in any fracture group could be found. Most injuries were caused by low energy trauma.

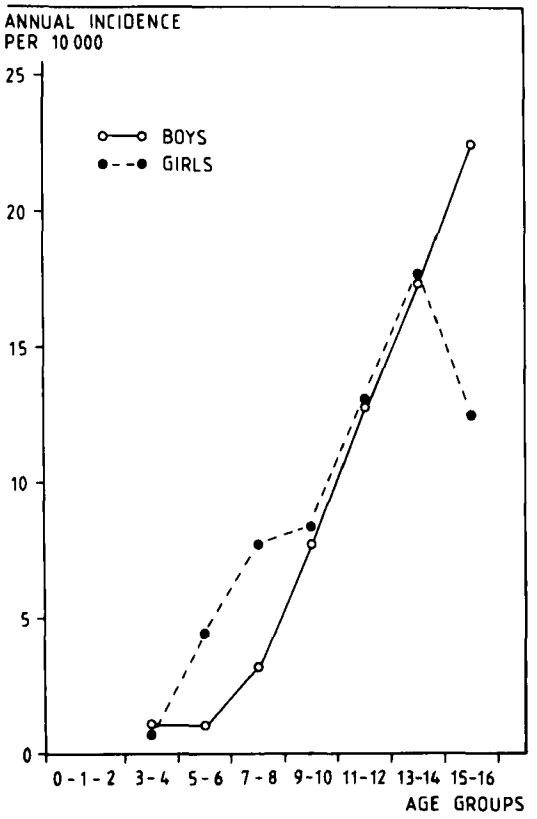


Figure 4. Age specific incidence.

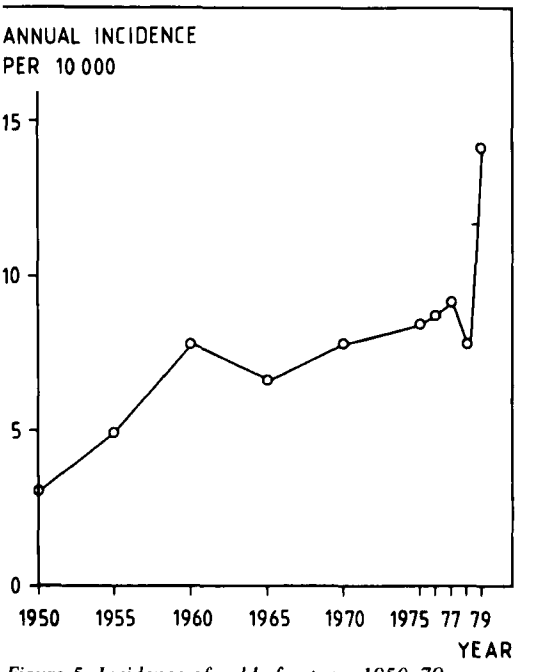


Figure 5. Incidence of ankle fractures 1950–79.

Figure 3 shows the seasonal variation with twice as many fractures registered in April and September, compared with July and December when the lowest frequency was observed. Assuming that the occurrence of fractures follows a Poisson distribution, the variations are on the limits or just outside the confidence limits of ± 2 s.d.

The incidence was calculated for each 2-year age group. Figure 4 demonstrates a steady increase during growth to the early teens, at which point the increase ceases, due to lower incidence among girls in the 15–16-year-group. Figure 5 shows the total incidence of childhood ankle fractures for each year studied: a significant increase has taken place over the years.

DISCUSSION

Supination-inward rotation is the most common mechanism in distorsion injury to the ankle.

Subsequently, fracture groups 1–3, 10, 12–13 account for the majority of cases.

The most striking result of this investigation is the high frequency of triplane and Tillaux fractures forming the third and fourth most common fracture group respectively. Usually these fractures have merited publication as case reports (Kleiger & Mankin 1964, Marmor 1970, Lynn 1972). In 1957, Johnson & Fahl found, in a series of 27 fractures, 10 cases which with today's knowledge could be classified as triplane fractures. Also Spiegel et al. (1978) and Dias & Tachdjian (1978) observed a higher frequency of the Tillaux and triplane fractures than could be expected from previous reports. Our results are also consistent with theirs. Cooperman et al. (1978) and Kärrholm et al. (1981) have described triplane fractures with a different appearance from that originally described by Marmor (1970) and Lynn (1972). With tomography and CT, Kärrholm et al. (1981) found triplane fractures consisting of 2, 3 and 4 fragments. Sophisticated classification in fracture types found by Kärrholm et al. (1981) was not possible for us, since our investigation was retrospective. The mechanism of production of the Tillaux and triplane fractures might represent different degrees of the same type of trauma (Dias & Tachdjian 1978) and the resemblance between the quadrilateral shape of the Tillaux fracture fragment and the lateral epiphyseal fracture of the triplane fracture is striking. Kleiger & Mankin (1964) observed that the distal tibial epiphysis closes first in the middle, then in the medial and finally in the lateral part. This could explain the shape of the fracture fragment in juvenile Tillaux fractures (Kleiger & Mankin 1964).

The difference in mean age between groups 1 and 2 and 1 and 2–3, respectively, indicates that the mechanical properties of the distal tibial growth plate and the bone in the metaphyseal region vary with age, although chronological age does not strictly reflect bone age. The difference may also be partly explained by increasing weight, muscular force and activity with age, factors which contribute to higher energy levels of trauma in the older year groups. However, distorsion trauma does not always produce epiphyseal line injuries and five cases of twelve in group 16 had, in spite of open growth plates, fractures that could not be classified according to Dias & Tachdjian (1978). These fractures resembled fractures or combinations of fractures usually seen among adults. Only one fracture was observed in group 6, and its classification as a separate group can be questioned.

The seasonal variation of ankle fractures is virtually the same as is earlier found in Scandinavian investigations of childhood accidents (Kølle-Jörgensen 1971, Nathorst-Westfelt 1982). The lower frequency of fractures registered during the summer could to some extent be explained by the fact that part of the child population leaves the city during the holidays. These children could of course sustain a fracture outside Malmö, which would not be radiographed in the city and therefore not registered. However, this would produce a lower rate of fractures not requiring reduction in summer, which was not the case.

The preponderance of right-sided fractures in this material was obvious. Side-difference in children's fractures is to our knowledge only found in supracondylar fractures of the humerus which are more frequent on the left side (Henrikson 1966). In their study of ankle fractures in children Vahvanen & Aalto (1980), found a left : right ratio of 179 : 131.

The increased incidence of the early teens seems to be followed by a decrease in the 15–24-year-groups (Nilsson 1969). However, a strict comparison is not possible since different time periods are covered by the studies and therefore interference from secular changes cannot be ruled out. The incidence of ankle fractures in boys increases from age group 13–14, being twice that recorded in women during the next two decades of life (Nilsson 1969). The factors contributing to the increasing incidence during the 30 years covered by this study cannot be fully explained. New types of games and an increasing participation in organized sport probably cause variations in fracture incidence: for instance, all nine fractures sustained when falling on roller skates or from skate boards occurred during the last 2 years studied. Some of the minor ankle injuries give symptoms which subside after a short period. Therefore, attitudes and tendencies in the population to seek medical advice also in-

terfere with the results. In an attempt to clarify this phenomenon, the incidence was calculated for fractures for which the parents will definitely bring the children in to a doctor. For this purpose diaphyseal fractures of long bones were chosen but no secular changes similar to those found in ankle fractures were observed (Landin, in manuscript).

REFERENCES

Alffram, P. A. (1964) An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population. *Acta Orthop. Scand.*, Suppl. 65.

Alffram, P. A. & Bauer, G. C. H. (1962) Epidemiology of fractures of the forearm. *J. Bone Joint Surg.* **44**-A, 105–114.

Bishop, P. A. (1932) Fractures and epiphyseal separation of the ankle: classification of 332 cases according to the mechanism of their production. *Am. J. Roentgenol.* **28**, 49.

Broström, L. (1966) Sprained ankles. Surgical treatment of "chronic" ligament ruptures. *Acta Chir. Scand.* **132**, 551.

Carothers, C. O. & Crenshaw, A. H. (1955) Clinical significance of a classification of epiphyseal injuries of the ankle. *Am. J. Surg.* **89**, 879.

Cooperman, D. R., Spiegel, P. G. & Laros, G. S. (1978) Tibial fractures involving the ankle in children. The so-called triplane epiphyseal fracture. *J. Bone Joint Surg.* **60**-A, 1040–1046.

Danielsson, L. G. (1980) Avulsion fracture of the lateral malleolus in children. *Injury* **12**, 165–167.

Dias, L. S. & Tachdjian, M. O. (1978) Physeal injuries of the ankle in children. *Clin. Orthop.* **136**, 230–233.

Gerner-Smidt, M. (1963) *Ankelbrud hos børn.* Nytt Nordiskt Förlag, Copenhagen.

Henrikson, B. (1966) Supracondylar fracture of the humerus in children. *Acta Chir. Scand.*, Suppl. 369.

Horak, J. & Nilsson, B. (1975) Epidemiology of fracture of the upper end of the humerus. *Clin. Orthop.* **112**, 250–253.

Johnson, E. W. & Fahl, J. C. (1957) Fractures involving the distal epiphysis of the tibia and fibula in children. *Am. J. Surg.* **93**, 778–781.

Kärrholm, J., Hansson, L. I. & Laurin, S. (1981) Computed tomography of intra-articular supination-eversion fractures of the ankle in adolescents. *J. Ped. Orthop.* **1**, 181–187.

Kleiger, B. & Mankin, H. J. (1964) Fracture of the lateral portion of the distal tibial epiphysis. *J. Bone Joint Surg.* **46**-A, 25–32.

Kølle-Jörgensen, P. (1971) *Child accidents. A medico-social study of 4820 accidents.* Munksgaard, Copenhagen.

Lynn, M. D. (1972) The triplane distal tibial epiphyseal fracture. *Clin. Orthop.* **86**, 187–190.

Marmor, L. (1970) An unusual fracture of the tibial epiphysis. *Clin. Orthop.* **73**, 132–135.

Nathorst-Westfelt, J. Å. R. (1982) Environmental factors in childhood accidents. *Acta Paediat. Scand.*, Suppl. 291.

Nilsson, B. E. (1969) Age and sex incidence of ankle fractures. *Acta Orthop. Scand.* **40**, 122–129.

Salter, R. B. & Harris, W. R. (1963) Injuries involving the epiphyseal plate. *J. Bone Joint Surg.* **45**-A, 587–622.

Spiegel, P. G., Cooperman, D. R. & Laros, G. S. (1978) Epiphyseal fractures of the distal ends of the tibia and fibula. *J. Bone Joint Surg.* **60**-A, 1046–1050.

Vahvanen, V. & Aalto, K. (1980) Classification of ankle fractures in children. *Arch. Orthop. Traumat. Surg.* **95**, 1–5.

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