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Calcaneal apophysitis: a quantitative radiographic evaluation of the secondary ossification center

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Abstract *Background:* Calcaneal apophysitis in children is a self-limited condition that may interfere with walking and physical performance in sports, thus causing concern to the patient and parents. There is still controversy about the significance of the radiographic changes in children with heel pain, since the report of Sever in 1912. One of the reasons is that normal children may display a considerable variation in the radiographic aspects of the secondary ossification center of the calcaneus at different ages. *Methods:* In this investigation, the developmental aspects of primary and secondary ossification centers of the calcaneus were studied in radiographs obtained from healthy boys and from boys with calcaneal apophysitis. The normal population comprised 392 children and adolescents ranging in age from 6 to 15 years. There were 69 individuals with calcaneal apophysitis ranging in age from 8 to 14 years. Lateral standard radiographs were obtained of both heels, and a copper step wedge was used as a calibration to determine bone density. The following parameters were analyzed on the plain films: time of appearance, fusion and number of fragments of the secondary nucleus, area and bone densitometry of the primary and secondary ossification centers of the calcaneus. *Results:* In the normal population, the ossification of the secondary nucleus began at 7 years of age, and at 15 years of age, the nucleus was fused in all individuals. In the apophysitis group, the secondary ossification center was present and not fused in all individuals. Both secondary nuclei increased in size with age with no difference be-

tween the two groups. Regarding bone density, both the primary and secondary nuclei were less dense in the apophysitis group than their counterparts in the normal population. The most significant difference between the two populations referred to the degree of fragmentation, which was greater in the apophysitis group. *Conclusion:* Our data showed that the sclerotic aspect of the secondary nucleus of the calcaneus is a normal feature and, therefore, should not be used to establish the diagnosis of Sever's disease. The most consistent difference between the normal and apophysitis group was related to the more fragmented aspect of the secondary nucleus in the latter individuals, which may suggest a mechanical etiology for that condition.

Keyword Calcaneus · Apophysitis · Ossification center · Bone densitometry

Introduction

One of the first authors to report calcaneodynia in children and adolescents was Haglund [5], who described a clinical picture characterized by pain in the posterior and inferior region of the heel. A few years later, Sever [15] reported the same clinical picture in very active and overweight children, emphasizing the enlargement of the epiphyseal line of the ossific nucleus of the calcaneus on the X-rays, with cloudiness and obliteration of the epiphyseal line.

An explanation for calcaneal apophysitis was presented by Lewin [8], who pointed out that the clinical and radiographic aspects of the condition could be the result of inflammation caused by traction in opposite directions between the Achilles tendon and the plantar structures, leading to local congestion.

The radiographic aspect of the calcaneus of children was studied by other authors [1, 2, 3, 6, 7, 13, 14] who emphasized the presence of the sclerotic and fragmented aspect of the calcaneal apophysis in healthy and asymptomatic children. Michelli and Ireland [10] and Griffin [4]

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reported that calcaneal apophysitis is a common finding in 9- to 11-year-old individuals with no radiographic finding being specific for the condition, since they found that the secondary nucleus was fragmented and denser also in normal children. Prado et al. [13] considered the sclerotic aspect of the calcaneal apophysis to be an artifact caused by the profile view since it was not found on the axial view. Nery et al. [11] stated that the fragmentation of the calcaneal secondary nucleus was the most reliable radiographic finding in apophysitis, and O’Ferral [12] noted the disappearance of the areas of disintegration after treatment of the apophysitis.

The radiographic aspect of the secondary nucleus of the calcaneus in children with heel pain remains controversial. Some authors consider the findings to be nonspecific, while others emphasize either the sclerotic changes or the fragmented aspect.

In the present investigation, we studied the radiographic characteristics of the calcaneus in children with apophysitis and compared them to the normal population (asymptomatic individuals) using a quantitative evaluation.

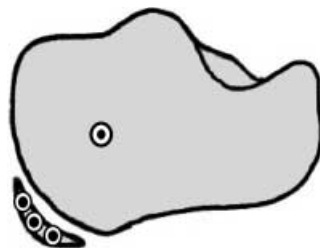
Patients and methods

The present investigation was approved by the Human Investigation Committee of our hospital. Two population samples were included in this study. The control group consisted of healthy individuals recruited from educational institutions, with no past history or complaints of the locomotor system, with normal physical appearance, and without foot abnormalities. Male children and adolescents ranging in age from 6 to 15 years were included in this group. A brief orthopedic examination was carried out, with special emphasis on the overall conditions of the individual, gait, and physical examination of the lower limbs, especially the feet.

The group with apophysitis consisted of patients treated at our institution for heel pain of at least 6 months’ duration on only one side during walking or on palpation, with no local signs such as inflammation or deformity. The main clinical finding was tenderness elicited by medial and lateral heel compression [10]. The foot was otherwise normal. Specific conditions that might cause calcaneal pain such as infection, fracture, and tumors were excluded.

For this investigation, all the individuals had both hindfeet X-rayed in the lateral position with a single exposure. A calibration copper step wedge made of 10 superimposed layers of 0.7 mm thick copper sheets was placed equidistant between the two heels to enable the study of optical density and the estimation of bone density. For the control group, a preliminary statistical analysis showed no difference between the sides, and thereafter the right foot was selected for the complete analysis. For the apophysitis group, only the symptomatic side was analyzed. First, on the plain films, the primary and secondary nuclei were outlined on a digitalizing table, and the corresponding areas of the nuclei were obtained with a computer program software.

Fig.1 Schematic drawing illustrating the locations where the optical density was measured in the primary and secondary ossification centers of the calcaneus



To evaluate bone density, the radiographs were read using a Macbeth TD528 phodensitometer. Zero adjustment was obtained with opaque glass. Every 0.7 mm step image was read, followed by the secondary nucleus in areas located in its upper, middle, and lower parts. In the case of a fragmented nucleus, at least one reading was obtained for each main fragment. Next, the density of the primary nucleus was read in one area located in the central part of the body of the calcaneus (Fig.1). The densitometry data of the calcaneal images were converted and expressed as copper thickness [9].

Statistical analysis

Analysis of variance of the primary and secondary centers of ossification of the calcaneus was applied to the mean values of density variables and was found to be significant. Turkey’s test was then performed. Thus, it was possible to evaluate at what ages the increase of each variable was significant. The level of significance was set at 5%.

Results

The distribution of age of appearance and of closure of the calcaneus ossification center in the normal population is shown in Fig. 2. For the normal population, the number of fragments of the secondary ossification center was predominantly one for all age groups studied. A few individuals had two and, rarely, three or more fragments (Fig. 3).

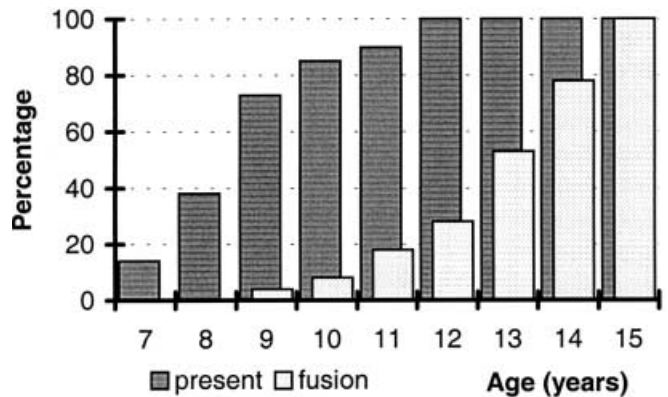


Fig.2 Age of appearance and fusion of the calcaneal secondary nucleus of ossification

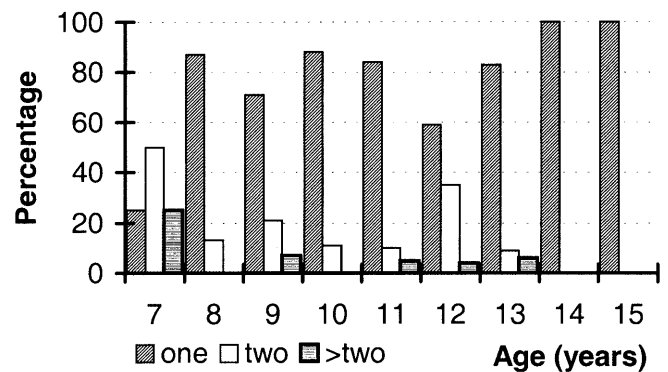


Fig.3 Number of fragments of the calcaneus secondary ossification center in the control population

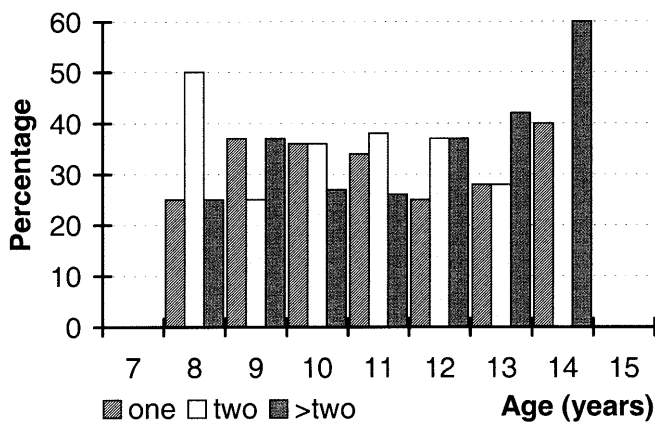


Fig. 4 Number of fragments of the secondary calcaneus ossification center in the apophysitis group

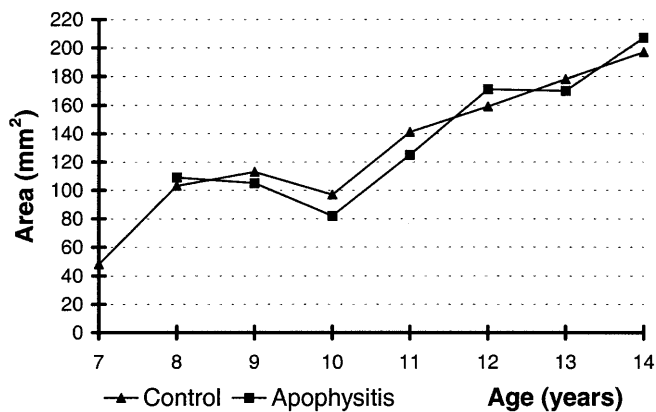


Fig. 6 Increase of the area of the secondary calcaneal ossification center in the control and apophysitis groups with age

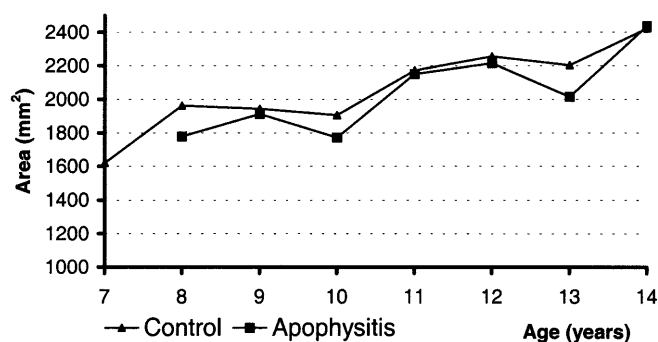


Fig. 5 Increase of the area of the primary calcaneal ossification center in the control and apophysitis groups with age

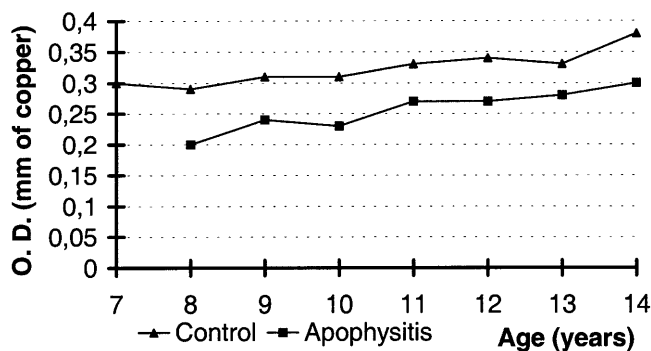


Fig. 7 Variation of the densitometry of the secondary calcaneal ossification center in the control and apophysitis groups with age

A more homogeneous distribution of the number of fragments was observed for all ages in individuals with apophysitis (Fig. 4). In this group, there was a peak of incidence of calcaneodynia at 11 years of age.

On lateral X-ray, the areas of the primary center showed a steady increase with age for both groups but with lower limits for the apophysitis group; the differences were statistically significant ($p=0.02$; Fig. 5). The area of the secondary ossification center was not different between the groups ($p=0.96$; Fig. 6).

Optical density analysis for the control group showed that the secondary ossific nucleus was denser (average 0.32 mm of copper equivalence) than the primary nucleus (average 0.25 mm of copper equivalence) ($p<0.0001$). For the symptomatic group, the ossific nucleus was still denser (average 0.26 mm of copper equivalence) than the primary nucleus (average 0.21 mm of copper equivalence), the difference was smaller but still statistically significant ($p<0.0001$).

The radiographic density of the primary nucleus was greater in normal individuals (average 0.27 mm of copper equivalence) than in the apophysitis group (average 0.21 mm of copper equivalence) ($p<0.0001$). The secondary ossification center was less dense (average 0.26 mm of copper equivalence) in the apophysitis group than in the

normal group (average 0.32 mm of copper equivalence) ($p<0.001$) (Fig. 7).

Discussion

Calcaneal apophysitis is a common cause of heel pain in children, is transient in most instances, and rarely causes significant disability, but may interfere with walking and physical performance in sports, thus causing concern to the patient and parents.

When Sever reported this clinical condition, the use of X-rays was becoming widespread, and diseases currently known as osteochondrosis were beginning to be described [15]. Therefore, the radiographic changes observed in the secondary nucleus of ossification of the calcaneus were attributed to ischemic changes, but years later, several authors showed that the sclerotic aspect was often observed in normal children [1, 2, 3], not indicating a pathological condition *per se*. But if the sclerotic changes are not seen as an important manifestation of Sever's disease today, changes such as fragmentation might be a more typical manifestation of calcaneal apophysitis [11].

Our results support the view that in calcaneal apophysitis the secondary ossification center tends to be more

fragmented than in the normal population (Figs. 3 and 4) and that the sclerotic changes observed in the secondary ossification center are a normal feature that should not be used to establish the diagnosis of calcaneal apophysitis. Moreover, our data showed that when the radiographic density of the secondary center was compared between the two groups, in fact, the ossific nucleus was less dense in the symptomatic children. If we consider that the primary ossification center of the calcaneus was also less dense in the apophysitis group than in the normal population, it seems reasonable to conclude that the increased sclerotic aspect of the secondary nucleus of the calcaneus on the plain films may be apparent. In addition, the lower density of both nuclei in Sever's disease as well as the smaller size of the primary nucleus in symptomatic children is probably due to disuse atrophy.

Our data also show that the age of appearance and fusion of the secondary ossification center is rather variable in normal individuals and that apophysitis has occurred only when the nucleus has appeared but not fused, as already found by others [1, 4, 12]. Therefore, any presumptive diagnosis of Sever's disease when the nucleus has fused or is absent should be reconsidered, as calcaneal apophysitis is a specific condition during a well-defined period of the growing age, strictly associated with the ossification process. We may speculate that the occurrence of ossification in the cartilaginous anlagen of the posterior tubercle of the calcaneus leads to a local disturbance, causing the region to be more vulnerable to the strong mechanical solicitations caused by the opposing forces of the Achilles tendon and plantar structures, as well as by the local impact that occurs with the heel strike. However, such speculation does not explain the peak of incidence of calcaneodynia found at 11 years of age, which was also observed by Brantigan [1] and Griffin [4].

In conclusion, our findings suggest that children with Sever's disease do not have growth disturbances in the calcaneal apophysis or any change in bone density consistent with a necrotic or a repair process. Thus, a vascular etiology for this condition, as observed in other types of

osteochondritis, is unlikely. The increased fragmentation of the ossific nucleus may reflect mechanical demands during a more vulnerable period of local ossification.

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