FROM THE CLINICA ORTOPÆDICA DELL' UNIVERSITÁ, FLORENCE, ITALI
(HEAD: PROF. O. SCAGLIETTI)

PLUS-VARIANT OF THE ASTRAGALUS AND SUBNORMAL SCAPHOID SPACE, TWO IMPORTANT FINDINGS IN KOEHLER'S SCAPHOID NECROSIS

By

O. SCAGLIETTI, G. STRINGA and M. MIZZAU

Among the numerous aetio-pathogenic hypotheses that have been advanced in connection with scaphoid osteochandritis of *Koehler*, one of the most likely theories is that which ascribes the condition to repeated microtrauma resulting from local static abnormalities, through the intermediary of local vascular disturbances. Not only is this theory in accordance with the anatomical situation, but it is also supported by the fact that the pathological and radiographical aspects show considerable similarity to those of conditions that are known to be due to microtrauma and vascular disturbances.

In accordance with this theory, and in analogy with what Hultén has written about malacia of the semilunar bone, in which he found that the radius extended farther in the distal direction than the ulna ('minus variant'), we have made a study of the variations of the lengths of the various components of the tarsus and their distances from each other in cases of scaphoid osteochondritis, as compared with normal feet. No such investigation has been reported in the literature up to now, although there have been some authors who have hinted at these aspects (*Brailsford*, 1948: reduction of the space between the astragalus and the first cuneiform bone).

MATERIAL

We collected and examined 100 cases of *Koehler's* disease; 75 of these were found in the records of the Orthopaedic Clinic of our University, from these we selected a group by eliminating cases that seemed somewhat doubtful or where the evolution was insufficiently documented. The other 25 cases we found in the literature on osteochondritis of

Koehler, we included these because we wanted our material to be more varied, especially in regard to possible differences of radiological technique.

Of the patients concerned, 14 were 3 years old, 22 were 4 years, 24 were 5 years and 35 were 6 years old; the remaining 5 patients were younger or older. There were 75 male and 25 female patients.

In order to obtain normal material for purposes of comparison, we have made radiograms of one foot in 100 children who had been hospitalised for diseases not involving the lower extremities. In this way the age distribution was the same as in the pathological group.

METHOD

Since, generally, we had at our disposal a series of radiograms for every case, we selected for our measurements that radiogram in which the fragmentation or increased density was most distinct. The individual cases presented no changes of the indices selected with the various stages of development of the diseases (initial stage, fragmentation stage etc.); only age modified indices.

The radiograms which we studied were taken in the anteroposterior projection. The patient is seated, with the sole of the foot supported flat in the roentgen table that has been placed in the horizontal position; the radiation bundle is directed exactly at right angles to the plane of the table.

In the radiograms of the foot in the antero-posterior projection, we

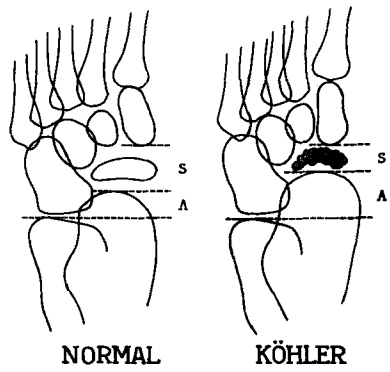

Fig. 1.

Projection of the astragalus (A) and scaphoid space (S) in the normal foot (left) and in Koehler's scaphoiditis (right). The projection of the astragalus is more pronounced in the pathological case, and the scaphoid space is smaller.

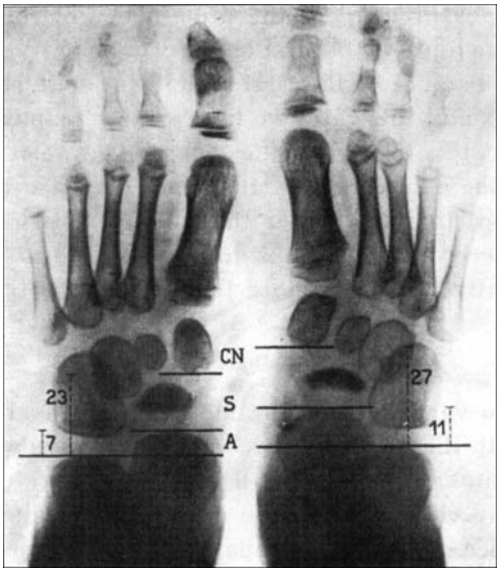

Fig. 2.

B.C.A., 3-year-old boy. Comparison of the feet (the right foot affected with Koehler's disease, the left one normal) for demonstration of the greater astragalic projection on the affected side.—The ratio of the distance from the first cuneiform bone to the calcaneus (CN) and the projection of the astragalus beyond the calcaneus (A) constitutes the so-called 'scaphoid index'; the greater the space allowed for the scaphoid bone, the higher this index. Example:

on the left (normal):

A = 7 mm.; CN = 23 mm. 23 : 7 = 3.25 = scaphoid space index (S)

on the right (Koehler's disease):

A = 11 mm.; CN = 27 mm. 27 : 11 = 2.45 = scaphoid space index (S)

The astragalus projects farther in Koehler's disease (11 mm. compared with 7) and the space available for the scaphoid bone is less (2.45 compared with 3.25).

first of all determined the axis of the foot, for which we took the extension of the bisectrix passing through the centre of the angle formed by the converging external margins of the astragalus and the calcaneus.

Perpendicularly to the axis we have drawn in three straight lines (figs. 1, 2), each touching the following points: the distal limit of the calcaneus, the distal limit of the astragalus, and the proximal limit of the first cuneiform bone. Taking the first line (the one touching the calcaneus) as a basis, we have measured the distance from this line to the other two lines (touching the astragalus and the first cuneiform bone, respectively); in this way we obtained two values. The first value

represents the measurement of the prominence of the astragalus, the second that of the limit of the first cuneiform bone. We then calculated the ratio of the distance of the first cuneiform bone and the distances of the astragalus and this ratio we have called 'scaphoid space index'. This index indicates, relatively, the distance between the first cuneiform bone and the astragalus, i.e. the space occupied by the navicular bone. It is evident that the higher the value of this index, the greater the distance between the astragalus and the cuneiform bone; the higher index consequently reflects a more favourable situation.

FINDINGS

In view of the variability of the astragalus measurements and the other indices with the subjects' age, we have subdivided the entire material into 4 groups: of 3, 4, 5 and 6 years.

For each group we calculated the average astragalic projection and the scaphoid space index, with comparison of the normal subjects with the patients with osteochondritis. In patients aged 3 years with *Koehler's* disease the astragalus projects on the average 7 mm., and the index amounts to 2.63; in the normal foot the astragalus projects, on the average, 5.8 mm. and the index is higher (3.39). Fig. 3.

In the older age groups, the differences between the normal and the pathological values grow larger. In the 4-year-olds, with *Koehler's* di-

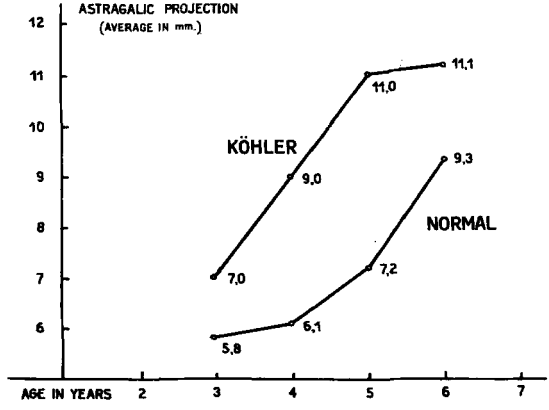

Fig. 3.

Graph listing the average projection of the astragalus in mm. as related to age, calculated for 100 cases of Koehler's disease and for 100 normal feet. The higher line indicates the projection in Koehler's disease, the lower line, the projection in normal feet.

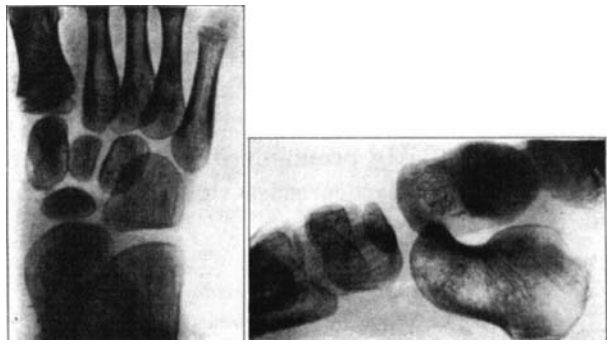

Fig. 4.
T.E., 4-year-old boy. Normal foot. A = 6 mm.; CN = 15 mm. Scaphoid index 2.5.

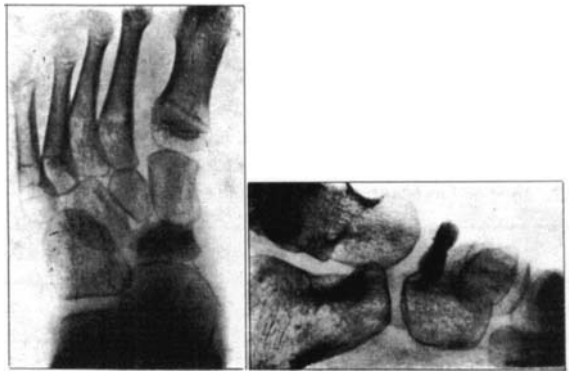

Fig. 5.
P.A., 6-year-old boy. Schaphoid necrosis of Koehler.
A = 14 mm.; CN = 23 mm. Scaphoid index 1.6.

sease, the astragalus projects on the average 9.0 mm., in the 4-year-olds with normal feet it projects 6.1 mm. The scaphoid space indices in these two groups are 2.27 and 2.80, respectively. In the 5-year-olds, the astragalus projects 11 mm. in the cases of *Koehler's* disease, and 7.2 mm. in the normal subjects; the scaphoid space indices are 1.88 and 2.73, respectively. In the 6–year group, the astragalus projects 11.1 mm. in *Koehler's* disease and 9.3 mm. in the normal children and the scaphoid space indices are 1.81 and 2.1, respectively. (Fig. 3, tables 1, 2).

To sum up, in cases of osteochondritis of *Koehler* the astragalus projects farther, on the average 3.8–1.2 mm. Expressed in percentages, this plus value of the astragalus in the pathological foot as compared

with the normal foot is 35 % in the 5-year-olds, 33 % in the 4-year-olds, 18 % in the 3-year-olds and 16 % in the 6-year-olds.

Our findings further show that the space allowed for the scaphoid bone is less in feet affected with *Koehler's* disease than in normal feet; this difference is particularly pronounced in the younger age groups (up to 1/3 less) and gradually decreases (to approx. 0.2) (fig. 1–2).

TABLE 1
Astragalic projection
(average values: 200 cases).

Age	Normal	Koehler	Plus-variant average
3 years	5.8	7.0	+ 18 %
4 years	6.1	9.0	+ 33 %
5 years	7.2	11.0	+ 35 %
6 years	9.3	11.1	+ 16 %

TABLE 2
Scaphoid space index
(average values in 200 cases).

Age	Normal	Koehler
3 years	3.39	2.63
4 years	2.80	2.27
5 years	2.73	1.88
6 years	2.10	1.81

On the basis of the values obtained we determined a 'threshold' of the astragalic projection, i.e. a liminal value beyond which the situation can be regarded as pathological. We regard as the maximal normal projection of the astragalus: 6 mm. for 3-year-olds, 7 mm. for 4-year-olds, 8 mm. for 5-year-olds, 10 mm. for 6-year-olds. Among the patients with *Koehler's* osteochondritis, this limit is exceeded by 70 % of the 3-year-olds, by 100 % of the 4-year-olds, by 90 % of the 5-year-olds and by 70 % of the 6-year-olds. Over the total number of cases in all 4 age groups, 82 % of those affected with *Koehler's* disease showed an astragalic plus variant.

On the one hand, of the group of normal children, the following percentages remained below this liminal value: 70 % of the 3-year-olds, 100 % of the 4-year-olds, 80 % of the 5-year-olds and 65 % of the 6-

year-olds. Over the total number of subjects in the 4 age groups, 76 % of the normal subjects had an astragalic projection of less than the pathological threshold.

The findings are similar as regards the scaphoid space index: with limits fixed on the basis of the average of the measured values, we found that 75 % of those affected with osteochondritis had a pathological index.

In conclusion it may be stated that from four-fifths to three-quarters of those affected with *Koehler's* disease presented an astragalic projection and a decrease of the scaphoid space (fig. 4) of such a degree that they could be regarded as significant for our investigation. Contrastingly, only one-fifth to one-fourth of feet not affected with *Koehler's* disease showed these abnormal measurements (fig. 4).

DISCUSSION

As appears from the above, this work is based on measurements in millimeters. Objections might be made regarding the value of such measurements and the possible influence of variations of certain factors. Objections and factors must here only shortly be discussed, owing to space limitation.

1. The technique of radiographical projection. With the central beam exactly at right angles to the plane on which the foot rests, a certain value is found; a deviation of 10° of the beam has been found to cause considerable changes of the measurements obtained (one-fourth, one-third). It is therefore essential that the projection is perfectly vertical to the plane.

2. The measurement on the radiogram. An error can be made in drawing in the axis of the foot; a 10-degree deviation of the axis leads to an error of 1 mm., plus or minus for the astragalus, and slightly more for the cuneiform bone.

Furthermore, the same distances may be measured differently by different investigators. If we suppose an error of 1 mm. more or 1 mm. less (the error will very seldom be greater) for each bone, the indices calculated will show a plus or minus variation of one decimal. The indices we have found always showed 2–4 times as much difference.

3. The position of the foot. Alterations of a certain degree will, however, result when the forefoot is adducted or bent inward to an appreciable extent, but in such cases the radiogram cannot be used.

4. The shape of the foot. A pronounced cavus shape of the foot chan-

ges the findings, so that the astragalus appears to project less and the index is only slightly increased. Should we believe that in almost the whole series of 100 cases of scaphoid osteochondritis the feet have been radiographed in a flat position, which might have shifted the astragalus forward on the radiogram? The latter explanation might in itself constitute an aetio-pathogenic interpretation, but we prefer to believe that our findings are not the result of flatness or cavus posture of the feet, but reflect an actual plus variant of the astragalus.

5. Age of course has an effect on the measurement of the astragalus and on the scaphoid space index. However, the age-linked modifications always remain within the limits of the normal or of the pathological measurements; actually, as we have seen, every age group of one year has its own average value of astragalic projection and of scaphoid space index, the values changing simply into the average values of the next year.

6. Stage of development of the disease. We observed no correlations between the stage of the diseases (stage of densification, stage of fragmentation etc.) and the above-mentioned values. With the passing of the months and the progress of the disease the only change of the values is to be attributed to advancing age.

CONCLUSIONS

The measurements which we made in 100 children with *Koehler's* scaphoid osteochondritis divided into age groups (3, 4, 5 and 6 years) have shown that the astragalus in these cases projects farther than in a similar series of normal children; it also emerged that in *Koehler's* disease the space available for the scaphoid bone, expressed as the ratio of the distances of the astragalus and of the first cuneiform bone, was less than normal. These differences may be regarded as statistically significant, in view of the uniformity of the case material and of the numerical values of the differences encountered.

In the preceding pages we have discussed the objections that might be raised in connection with the validity of our findings, in connection with the possible variations resulting from inaccurate projections, the position of the foot, the differences of measuring on the radiogram. In our opinion all these sources of error have been eliminated.

The plus-variant of the astragalus and the decrease of the scaphoid space are found in the large majority of the cases of *Koehler's* disease

(82 %), but not all. The opposite is true of the normal subjects, in some of whom pathological values could be observed.

The conclusion drawn from these facts is that the plus-variant and the decrease of the scaphoid space are anatomical conditions which predispose to the disease and facilitate its development but are not essential requirements.

We merely present our conclusion that, if our interpretation has been correct, there exists in the majority of the cases of *Koehler's* disease an abnormal anatomical condition, and in our opinion it is only natural to presume that there is some aetio-pathogenic link.

SUMMARY

1. In 100 feet of children affected with *Koehler's* scaphoiditis, divided into age groups, the projection of the astragalus beyond the calcaneus was measured in millimeters on radiograms, made in the anteroposterior projection by a standardised technique. This astragalic projection was found to be greater in the cases of *Koehler's* disease than in 100 normal children.

2. The term 'scaphoid space index' is used for the ratio of the distances: calcaneus – first cuneiform bone and calcaneus – astragalus. This ratio was lower in the 100 cases of *Koehler's* disease than in the 100 normal children.

3. Reference is made to the possible sources of error in the finding of these figures: projection, measuring, position of the foot etc.

4. It is concluded that the increased projection of the astragalus and the decreased scaphoid space may play a part in the aetio-pathogenesis of *Koehler's* disease.

RESUME

1. Dans 100 pieds d'enfants atteints de la scaphoïdite de Koehler, répartis en groupes suivant l'âge, la projection de l'astragale derrière le calcanéum a été mesurée en mm sur les radiogrammes pris en projection antéro-postérieure selon une méthode standardisée. On a découvert que la projection de l'astragale était plus grande dans les cas de maladie de Koehler que chez 100 enfants normaux.

2. Le terme "indice de l'espace scaphoïde" est utilisé pour indiquer le rapport entre les distances: calcanéum – premier os cunéiforme et calcanéum-astragale. Ce rapport est moins élevé dans les 100 cas de la maladie de Koehler que chez 100 enfants normaux.

3. Il est fait allusion aux sources possibles d'erreur dan le calcul de ces données: projection, mensuration, position du pied, etc.

4. Il est conclu que la projection accrue de l'astragale et la diminution de l'epace scaphoïde peuvent jouer un rôle dans l'étude de l'étiologie et de la pathogénic de la maladie de Koehler.

ZUSAMMENFASSUNG

1. In 100 Füssen von Kindern, die in Altersgruppen aufgeteilt wurden und die an der Köhler'schen Naviculareeskrankung litten, wurde das Vorspringen des Talus über den Calcaneus hinaus in Millimetern an Röntgenbildern gemessen, die in der antero-posterioren Projektion gemäss einer standartisierten Technik vorgenommen wurden. Dies Hervorstehen des Talus war in Fällen von Köhlers Erkrankung grösser als bei 100 normalen Kindern.

2. Der Ausdruck "navicularer Raumindex" wird für das Verhältnis der Distanzen-Calcaneus-os cuneiforme I und calcaneus-talus-verwendet. Die Verhältniszahl war niedriger in 100 Fällen von Köhlers Erkrankung als in 100 normalen Kindern.

3. Die möglichen Fehlerquellen bei der Ermittlung dieser Zahlen-Projektion, Messung, Lagerung des Fusses etc., – werden erwähnt.

4. Man kommt zu der Schlussfolgerung, dass das vermehrte Vorspringen des Talus und der verminderte Naviculareraum möglicherweise eine Rolle in der Äthiologie der Köhler'schen Erkrankung spielt.

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