The ankle joint of man / a graduation thesis by Ann Elizabeth Clark from England. Presented to the Medical faculty of the University of Berne and accepted to be printed on the report of Prof. Dr. Aebey.

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THE ANKLE JOINT OF MAN

A

GRADUATION THESIS

BY

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FROM

ENGLAND.

PRESENTED TO THE
MEDICAL FACULTY OF THE UNIVERSITY OF BERNE

AND ACCEPTED TO BE PRINTED ON THE REPORT
OF

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THE ANKLE JOINT OF MAN.

Anatomists writing on the Ankle joint are found to differ considerably, not only as to the division of the joints forming the Ankle, but also as to the type on which the facets are formed, the direction of the axes, and the amount of movement permitted by the different parts. There seems room therefore for further examination into the nature of the joint, especially as the methods of examining joints employed by Professor Aeby might be expected to give more accurate results than those previously obtained.

At the same time it seemed well to make a similar examination of fœtal feet, with regard to the great normal difference which according to Hueter [1] exists between the bones of the newborn and adult.

The work was done at the Anatomical Institute of Berne under the direction of Professor Aeby, and I take this opportunity to thank him not only for the necessary material which he placed at my disposal, but also for the kind assistance through which alone the work was accomplished. The measurements were all made by

[1] Anatomische Studien an den Extremitätengelenken Neugeborner und Erwachsener. Virchow's Archiv f. Pathol. Anatomie. Bd. 25. S. 5, 83.

Klinik der Gelenkkrankheiten. 2. Aufl. 2. Theil, S. 35—110.

methods he had before applied to the examination of the Shoulder, Hip, Knee and Ankle joints. [1]

To obtain the forms and curves of facets of joints, flat cakes of white wax of about five mm. thickness are used. On one side the edge is bevelled to half this thickness, and cut as nearly as possible to the curve of the facet to be measured; it is then softened in a spirit flame, pressed gently on the facet and allowed to harden; during this pressure care must be taken that the wax is held at right angles to the surface. If the first impression given is not perfect, the process must be repeated until it exactly corresponds with the curve in question. The unbevelled side of the wax will now probably be uneven and will require levelling, after which the impression must be again applied, to see that it is not changed; if still exact, it is ready to be transferred to paper. For this, place the wax with its level side downwards on a piece of paper and trace the outline curve with a finely pointed pencil. All the principal curves of the facets may be obtained in this way, and with compasses the circles may be found, which would complete the arcs from which these curves are formed; the radii of these circles can then be measured and the geometrical form of the joint constructed. Besides the accuracy which this method gives, it has the great advantage of not injuring the joint measured and thus allowing an indefinite number of measurements to be taken from the same bone.

The angles which the axes of the bones and facets

[1] Aeby. Beiträge zur Kenntniss der Gelenke. Deutsche Zeitschrift für Chirurgie, Bd. VI. The Hip, Knee and Ankle joints were treated in the following Inaugural Dissertations.

Fr. Schmid. Ueber Form und Mechanik des Hüftgelenkes. Deutsche Zeitschrift für Chirurgie, Bd. V. — H. Pütz. Beiträge zur Anatomie und Physiologie des Sprunggelenkes. Zeitschrift für praktische Veterinärwissenschaft von H. Pütz. 1876. — H. Albrecht. Zur Anatomie des Kniegelenkes. Deutsche Zeitschrift für Chirurgie, Bd. VII.

would make with each other if produced till they cross, were found in the following way which has been previously described by Pütz. [1]

A sheet of paper was placed on the table, above this the prepared foot was fixed in the position it would have when resting on the ground; a string was then stretched over the foot in a line with the sagittal axis of the astragalus, and the line thus obtained was projected on the paper below the foot. In the same way the transverse axis was taken, and the line parallel with the hollow of the Astragalo-Tibial Facet. The astragalus was then removed and the direction of the sagittal axis of the Calcaneus, Sustentaculum Tali, and axis of rotation of the Posterior facet for the Astragalus obtained in the same way. The angles formed by the crossing of these lines are the ones required.

To find the vertical angles which the Talo-Calcaneal facet, and the Sustentaculum Tali made with the horizontal axis of the calcis, and that which the longest diameter of the Astragalo-scaphoid facet made with the transverse axis of the astragalus, the bones were placed so that the line of their axes should correspond with the level of the table on which they were, a straight wire was then fixed parallel with the direction of the facet to be measured, and the angle which this wire made with the table found by a quadrant.

The movements of the joints were measured by the Goniometer constructed by Professor Aeby which has been described by F. Schmid. [2] This instrument is a simple disk, on an upright support, divided into 360° and with a movable indicator fixed in its centre, one arm of which extends beyond its edge. A clamp fixed to the Tuber

[1] Beiträge zur Anatomie und Physiologie des Sprunggelenkes. Inaugural-Dissertation. Bern 1876.

[2] Archiv für Anthropologie. Bd. VI., S. 185. Ueber die gegenseitige Stellung der Gelenk- und Knochenaxen der vorderen und hinteren Extremitäten bei Wirbelthieren.

calcis held the foot in such a way as not to interfere with the free movement of the joints. To measure the movement of the Talo-crural joint the foot was placed in extreme dorsal extension, the goniometer being in front of it, with the indicator parallel with the long axis of the Tibia. The degree marked by the indicator having been noted, the position of the foot was changed to that of extreme dorsal flexion and the indicator again brought parallel with the Tibia. The number of degrees between its first and last position gives the extent of movement possible for the joint. As by this method, there is room for some inaccuracy, to lessen it the mean result of four such measurements was taken in each case.

In the case of one adult and all the fœtal feet a distinction was made between the degree of flexion of the Talo-crural joint, when the Talo-tarsal joint was fixed and when it was free.

The movement of the Talo-tarsal joint was measured in the same way, the foot being first supinated while in extreme dorsal flexion. The movement between the Talus and Calcaneus and Scaphoid being first taken, with the anterior part of the foot fixed, then the anterior part of the foot was set free so as to obtain the whole amount of supination and pronation which the foot allows.

Having explained the methods used, I will now go on to a more particular description of the separate joints forming the Ankle.

TALO-CRURAL JOINT.

This joint connects the Tibia and Fibula with the Astragalus.

The facet which governs the form of the joint is found on the superior and posterior surfaces of the body of the Astragalus. It is wider in front than behind from the converging of the lateral sides, concave from side to side, and convex from before backwards and has been described by Henke[1] and Hueter[2] as part of a cylinder with a radius of an inch. The following table shows that though sometimes part of a true cylindrical figure, more often the convexity is irregular, being greater in front than behind, whilst at the same time the radii of the internal and middle part of the facet are so constantly smaller than the external, that it seems justifiable to speak of it as being part of a cylindrical cone rather than as part of a cylinder. The radii rarely amount to an inch (3 cm.) but more nearly approach the 2 cm. spoken of by Henke as the radius of the depressed middle part of the facet. I have given but one radius for the convexity on the outer side because that convexity does not extend so far back as the inner and middle lines, being cut short by the small flattened triangular facet which lies between the posterior part of the superior facet and the external lateral facet which articulates with the external malleolus.

[1] Anatomie und Mechanik der Gelenke 1863. S. 253.

[2] Klinik der Gelenkkrankheiten. Zweite Auflage. 1877. Bd. II. S. 29.

		RADII IN mm OF CURVES OF TALO-CRURAL JOINT.								DEGREES OF THE ARCS OF THE MIDDLE CURVES			
		Facet on Astragalus						Facet on Tibia		Astragalus			TIBIA
		Middle		Internal side		External side		Middle					
		Ant. end	*Post. end*	*Ant. end*	*Post. end*	*Ant. end*	*Post. end*	*Ant. end*	*Post. end*	*Ant. arc*	*Post. arc*	*Sum of the two arcs*	
	Adult Feet.												
1	Left Female . .	22.8		24.0		23.2		24.8		105		105	73
2	Right Male . . .	18.3	30.0	18.5	29.5	30.0		32.0		48	68	116	65
3	Left M.	17.0	23.5	17.2	22.5	22.0		24.0		85	43	128	68
4	Right F. . . .	18.0	20.0	17.5	20.0	20.0		20.0		63	55	118	77
4	Left F.	18.0		17.0	18.0	20.0		19.0	*	137		137	70
5	Right M. 14 yrs .	15.0	26.8	15.0	31.0	18.8		17.6	26	59	42	111	52
6	Right M. . . .	23.0	24.3	16.0	26.5	25.0		28.0		73	38	111	74
7	Left M. 22 yrs .	16.0	18.8	15.2	18.0	20.4		20.4		119	38	157	73
8	Right M. . . .	16.0	18.0	16.0	22.0	19.0		19.8		66	51	117	74
9	Right M. . . .	17.5	23.0	21.3		21.2	14.0	34.5		78	43	121	48
10	Left M.	25.0		25.8		24.0		28.5		93		93	65
11	Right M. . . .	21.5		17.2	27.0	17.2	24.2	24.5		116		116	80
12	Left M.	16.0	30.5	19.5	28.0	25.0		30.5		68	48	116	63
13	Left	21.2	35.5	26.0	31.5	26.5		35.5		50	52	102	52
14	Left	20.2		16.7	21.7	19.3	14.0	20.8		99		99	77
	Mean Number	19.1	23.8	18.8	24.4	22.1		26.6				116.4	67.4

* In this case a double curve

The facet on the Tibia which corresponds with the superior facet of the Talus is wider in front than behind, convex from side to side, and concave from before backward; this concavity was about the same in all parts, therefore the radius of the middle line is alone given. The elasticity of the ligaments uniting the fibula to the tibia allows the necessary widening of the posterior part when, with extreme dorsal flexion, it is brought forward over the wide part of the facet on the Astragalus; and the presence of the small triangular facet on the external edge of the Astragalus is explained by the pressing on it of the pad formed by these ligaments, and the loose folds of synovial membrane, which are found between the Tibia and Fibula with the foot in dorsal extension, or in its right angled position.

The internal side of the body of the Talus has a long narrow flat facet to articulate with the internal Malleolus; the external, a larger triangular one, flat from side to side, concave from above downward. The two Malleoli in articulating with these facets clasp the body of the Astragalus like the socket of a hinge.

The extent of the joint surfaces given by Henke and Hueter was for the

Astragaloid facet	120°
Tibial facet	80°

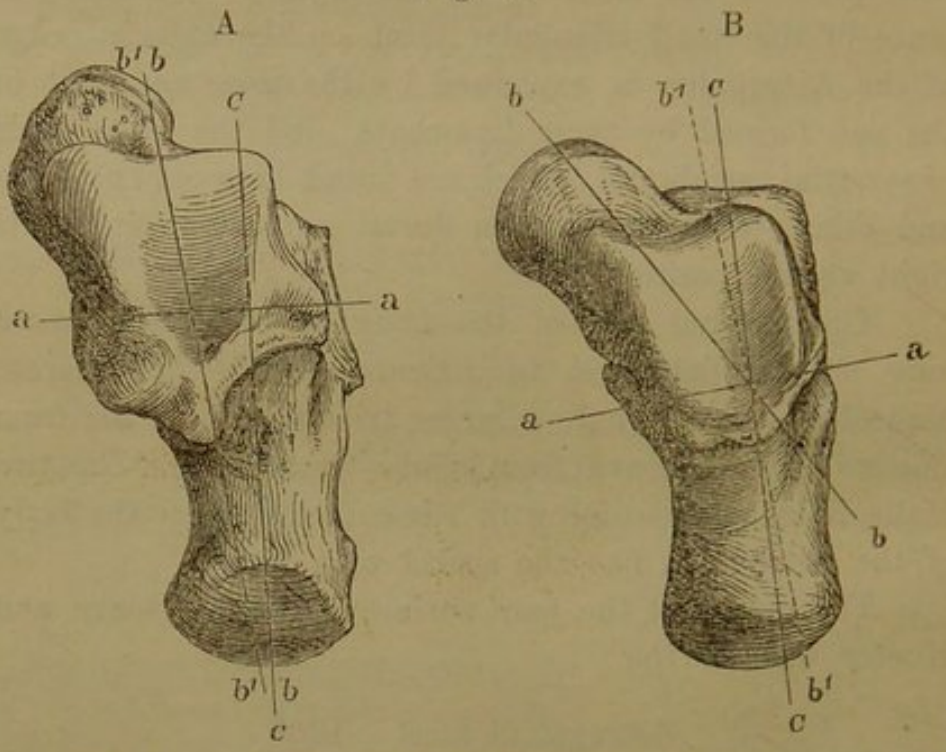
My measurements give about the same for the Astragalus, namely 116°.4 as the mean number; but for the facet on the Tibia 70° appears to be nearer the usual extent than 80°.

The axis of rotation of the Talo-crural joint must run from side to side in the frontal direction, because the primary movement is that of flexion and extension; if we use the radii of the curves of the superior facet on the Talus to find it, it will be found to pass from about the apex of the triangular facet for the external Malleolus

through the body of the bone, to come out on the internal side about five millimeters above the lower border of the neck of the Astragalus, and as much in front of the line at which the neck joins the body.

The axis of rotation is parallel with the transverse axis of the body of the Talus. The accompanying table gives the angles of the Astragalus etc. in the adult and fœtus.

Fig. 1.



Adult (A, 1/2 nat. Size) and Fœtal (B, 2/1 nat. Size) Astragalus and Calcaneus with their axes.

a a. Line parallel with the transverse axis of rotation of Astragalus.
b b. Sagittal axis of Astragalus.
b¹b¹. Line parallel with hollow of Astragalo-Tibial Facet.
c c. Sagittal axis of Calcaneus.

From this table it will be seen that the transverse axis of the body of the Astragalus has the same relation in the adult and fœtus to the line parallel with the depression in the facet of the Astragalus, and to the sagittal axis of the calcaneus, but while in the adult the depression in the Talus closely corresponds to the sagittal axis of the Astragalus, in the fœtus they differ by a

		DEGREES OF INTERNAL ANTERIOR ANGLES FORMED BY					
		Sagittal axis of Astragalus and Transverse axis of Astragalus.	Line parallel with hollow of Astragalo-Tibial facet and transverse axis of Astragalus.	Sagittal axis of Astragalus and Line parallel with hollow of Astragalo-Tibial facet.	Sagittal axis of Astragalus and Sagittal axis of Calcaneus.	Line parallel with hollow of Astragalo-Tibial facet and Sagittal axis of Calcaneus.	Transverse axis of Astragalus and Sagittal axis of Calcaneus.
	Adult Feet.						
1	Left F. . . .	86	86	0	6	6	93
2	Right M. . .	84	84	0	6	6	90
3	Left M. . .	83	83	0	12	12	95
4	Right F. . .	85	85	0	13	13	98
4	Left F. . . .	83	83	0	13	13	95
5	Right M. 14 yrs	80	80	0	17	17	97
6	Right M. . .	88	88	0	13	13	100
7	Left M. 22 yrs	80	80	0	15	15	95
8	Right M. . .	89	89	0	4	4	94
9	Right M. . .	90	90	0	11	11	101
10	Left M. . .	84	84	0	18	18	102
11	Right M. . .	92	92	0	13	13	105
12	Left M. . .	84	84	0	10	10	94
13	Left	80	80	0	12	12	93
14	Left	90	90	0	16	16	106
Mean Number		85.2	85.2	0	11.9	11.9	96.9
1	Right 2 yrs .	77	90	13	20	6	96
	Fœtal Feet.						
1	Left	66	90	24	38	14	103
2	Right 10 mo .	68	90	22	29	7	97
3	Right 8 mo .	65	90	25	42	17	107
4	Left 9 mo .	68	88	21	32	11	99
5	Right 9 mo .	79	92	13	27	14	106
6	Right 10 mo .	70	90	20	32	11	101
7	Right 9 mo .	65	90	25	38	13	103
8	Right 5 mo .	72	91	18	28	10	101
9	Left 9 mo .	69	88	21	25	4	92
10	Right 7 mo .	64	90	26	20	5	105
11	Left 6 mo .	68	91	23	32	9	100
12	Right 9 mo .	70	90	20	24	4	94
Mean Number		68.6	90.0	21.5	30.5	10.0	100.6

mean angle of 21°. This difference being caused by the great obliquity inwards of the head and neck of the bone, and not in reality affecting the body of the Astragalus, it has no effect on the direction of movement of the Talo-crural joint.

Henke, Hueter and Ludwig [1] say that the only movement allowed by the Talo-crural joint is that of flexion and extension with a slight screw movement in right foot to left and left foot to right. Henle [2] and Quain [3] say that, besides the flexion and extension, slight rotation is allowed when the foot is fully extended.

The extent of the movement is given by

Aeby	as	60°
Hueter	»	78°
Henke	»	90°

Langer gives the movement of the whole ankle at 110°.

In the following table, except in one adult and in the fœtal feet, only the united flexion and extension of the whole ankle is given — and this it will be seen proved in the adult to be always less than the 78° given by Hueter, and on an average less than 60°, the mean number being 51°, whilst that of the fœtus is greater than that of the adult, averaging 63°.

As for these measurements all muscles were removed, the ligaments alone being left, they do not affect Hueter's statement that the flexion and extension of the new born, from the check to flexion which the shortened dorsal extensors cause, is less than in the adult, but only show that, when the influence of the muscles is excluded, the joint in the infant allows a greater extent of movement than in the adult.

It may be noticed that the mean amount of movement (51°) closely corresponds to the average difference

[1] Physiologie des Menschen. 1858. Bd. I. S. 526.
[2] Anatomie des Menschen. 1853. Bd. I. Theil 2. S. 157.
[3] Elements of Anatomy. 1876. Vol. I. P. 174.

		Extent of flexion and extension of Ankle joint estimated in degrees.		Relative worth of rotation in full dorsal extension of Talo-Crural joint.			Extent of flexion and extension of Ankle joint estimated in degrees.		Relative worth of rotation in full dorsal extension of Talo-Crural joint.
		Talo-Crural joint.	*Talo-Crural & Talo-Tarsal joint.*				*Talo-Crural joint.*	*Talo-Crural & Talo-Tarsal joint.*	
	Adult Feet.								
1	Left F.		35°. 5	1	1	Right 2 yrs		63. 25	
2	Right M.		46°	0		Fœtal Feet.			
3	Left M.		39°. 5	1	1	Right 9 mo	46. 2	60. 0	0
4	Right F.		72°	0	2	Left 10 mo	45. 7	58. 0	0
4	Left F.		61°. 5	0	4	Right 9 mo	57. 7	74. 5	3
5	Right M. 14 yrs		48°	2	5	Left 9 mo	55. 7	71. 0	0
6	Right M.		47°. 5	0	6	Right 10 mo	65. 0	80. 7	0
7	Left M. 22 yrs		56°. 7	2	6	Left 10 mo	64. 7	73. 0	0
8	Right M.		62°	3	7	Right 9 mo	62. 5	66. 2	0
9	Right M.		54°. 2	0	7	Left 9 mo	56. 7	87. 7	0
10	Left M.		41°. 2	0	9	Right 9 mo	38. 5	47. 0	0
11	Right M.		45°. 7	0	9	Left 9 mo	49. 0	63. 7	0
12					10	Right 7 mo	50. 0	58. 0	3
13	Left		50°. 2	2	10	Left 7 mo	48. 7	76. 0	2
14	Left		42°. 7	0	11	Right 6 mo	58. 2	82. 2	0
15	Left	49. 0	59°. 2	1	11	Left 6 mo	45. 7	64. 7	0
					12	Right 9 mo	48. 5	68. 5	1
					12	Left 9 mo	44. 2	64. 2	2
Mean Number		49. 0	50°. 8				52. 3	68. 4	

(49°) between the size of the facets of the Talus and Tibia, an exact correspondence would not exist, because the depression in the neck of the astragalus in front of its facet, allows the facet of the Tibia to pass to a varying degree beyond the margin of the Astragaloid facet.

The obliquity of this facet, to which Langer and Henke have attributed the slight screw movement existing in this joint, was borne out by these measurements, for in the adult the line of the depression in the Astragalo-Tibial facet made an angle with the transverse axis of the Astragalus of 85°.2 but in the fœtus the obliquity does not exist, the two lines forming a right angle.

The rotation mentioned by Henle and Quain when the foot was in full extension, was found in some cases, the fixed point being the external malleolus. When this rotation did not exist, without exception there was a compensatory mobility between the Tarsal and Metatarsal bones.

In the fœtus the rotation was found less often than in the adult.

TALO TARSAL JOINT.

Henle[1], Langer[2] and Hueter[3] divide this joint into a *posterior part*, formed by the large posterior facet on the Calcaneus and the concave facet on the under surface of the body of the Astragalus, and an *anterior part*, by the three facets on the head and neck of the Astragalus, and the corresponding ones on the Scaphoid, Sustentaculum Tali, and Processus anterior of the Calcaneus.

Henke[4], Aeby[5] and Ludwig[6] give a *posterior* or *under Astragaloid joint*, formed by the facets common to the Calcaneus and Astragalus, and an *anterior* by the facet on the head of the Astragalus and that on the Scaphoid.

Meyer[7] gives an *under Astragaloid joint* like the last, but unites the joint between the Scaphoid and head of Astragalus, and that between the Cuboid and Calcaneus, into one as the *middle-foot joint*.

For the convenience of description, and also because it agrees better with what I believe to be the physiological division, I divide the Talo-Tarsal joint into three parts:

Posterior Talo-Calcaneal,
Anterior Talo-Calcaneal,
Talo-Scaphoid.

As the form of the Posterior Talo-Calcaneal influences the movement of the whole joint it is of most importance and will be first taken.

[1] Anatomie des Menschen. 1855. Bd. I. Theil 2. S. 158.
[2] Anatomie des Menschen. 1865. S. 161.
[3] Klinik der Gelenkkrankheiten. 1877. Bd. II. S. 101.
[4] Anatomie und Mechanik der Gelenke. 1863. S. 365.
[5] Der Bau des menschlichen Körpers 1871. S. 325.
[6] Physiologie des Menschen. 1858. Bd. I. S. 527.
[7] Anatomie des Menschen. 1861. S. 148.

Henle gives this joint the form of a cylinder, with a radius of about 28^{mm}, and an axis which runs from the posterior border of the outer surface to the anterior border of the inner surface, near its lower part, cutting the long axis of the foot at an angle of about 30°.

Henke describes the posterior facet on the Calcaneus, as formed from a flat cone whose point falls in the inner end of the Sinus Tarsi.

Meyer and Aeby say that the under Astragaloid joint is formed by an obliquely placed double cone whose point is in the Sinus Tarsi.

Langer and Hueter say that the posterior facet on the Calcaneus is formed from the segment of a cone whose apex Hueter places in the Sinus Tarsi, and this I believe to be correct.

Henke, Aeby, Ludwig and Hueter give a common axis for the posterior and anterior joints.

This axis Henke gives as beginning on the upper rough surface of the head of the Talus, a little to the inner side, and passing in a sagittal direction downwards and backwards, at about equal angles with the horizontal and perpendicular planes of the foot.

Ludwig describes it as directed from below, behind and out, to above, forwards and in.

Aeby, as passing forwards and upward at an angle of 45°.

Hueter, as running from the outer border of the insertion of the Achilles Tendon in front of the Sustentaculum Tali, in the neighbourhood of the Sinus Tarsi, through the body and neck of the Talus, to the inner part of the neck above the facet for the Scaphoid.

Langer says the axis of the posterior and anterior joints are in essentially the same direction, though not exactly identical, that of the posterior ascending obliquely from about where the Lig. Calc.-Fibulare is inserted in the Calcis to the insertion of the Lig. Navic. Dorsale.

Meyer gives the axis of the under Astragaloid joint as running from the middle of the upper border of the head of the Talus, through the Sinus Tarsi, to the under posterior border of the Calcaneus, whilst that of the middle joint is nearly horizontal.

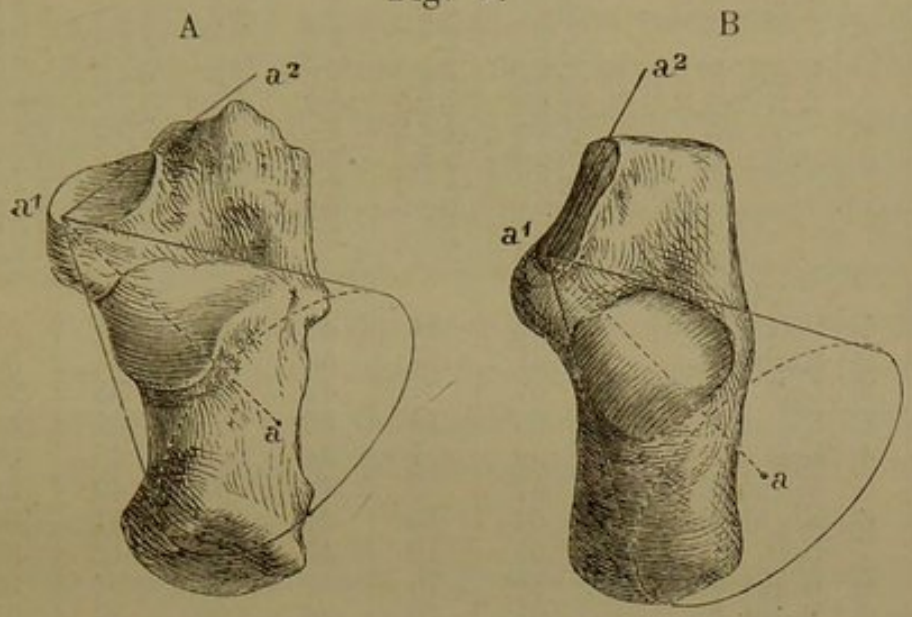
The large oval facet on the Calcaneus for the posterior Talo-Calcaneal joint is convex in its long diameter, but whilst the lower and outer part of the oval in its short diameter is perfectly flat, the upper and inner varies, being in some cases slightly concave, in others convex. The facet lies obliquely forwards and downwards across the bone, its long diameter forming a mean vertical angle of $41^{0}7$ with the horizontal plane of the Calcaneus.

As a basis for the measurement of the facet the line was taken from which its surface sinks on the one side forwards, down and out, and on the other backwards, down and in. At right angles to this line wax impressions were taken and the distance between noted. From the radii of the curves thus obtained and the distance between them, a cone could be constructed whose size is given in the following table. It is from a segment of this cone that the facet is formed.

In the fœtus, impressions of the facet were not taken, as from the smallness of the facet, and want of firmness of the cartilage which causes even gentle pressure to alter the form, accuracy could not be expected, and it seemed also the less necessary because as Hueter points out, the segment of the cone surface on the facet is much more evident in the fœtus than in the adult.

		Radii in mm of curves of Talo-Calcaneous facet from which cone is constructed.			Cone.		Radii in Millimeters of curves of Talo-Calcaneous facet.					
							a.		b.			
		a.	b.	Distance between curves.	Height in Millimeters.	Radii of Base in Millimeters.	*Radii of Posterior part of curve.*	*Radii of Anterior part of curve.*	*Radii of Posterior part of curve.*	*Radii of Anterior part of curve.*	Distance between curves.	Angle of Talo-Calcaneous facet with the Horizontal axis of the Calcaneus.
	Adult Feet.											
1	Left F.	21.0	15.0	9.0	23.0	21.0	23.0	36.0	16.5	32.0	13.0	42°
2	Right M.	24.0	15.2	10.0	16.0	24.0	15.0	37.0	13.0	20.0	10.0	35°
3	Left M.	26.0	19.3	12.0	41.0	26.0	20.0	34.8	14.5	34.8	11.8	45°
4	Right F.	18.5	14.0	8.2	32.0	18.5	18.3	28.0	21.0	32.0	10.0	37°
4	Left F.	16.5	11.0	9.5	24.0	16.5	16.0	30.0	18.5	39.8	10.0	39°
5	Right M. 14 yrs	24.3	16.5	11.0	26.0	24.3	26.8		20.5	25.0	13.0	46°
6	Right M.	24.3	16.0	13.5	31.0	24.3	22.0	31.8	21.5		10.0	58°
7	Left M. 22 yrs	23.0	12.8	13.0	21.0	23.0	12.0	27.8	18.5		11.0	45°
8	Right M.	23.0	13.0	13.0	18.0	23.0	27.0		21.0		10.0	42°
9	Right M.	22.6	16.0	11.0	30.5	22.6	24.5		16.5		9.0	35°
10	Left M.	21.2	14.0	8.0	13.5	21.2	23.5		16.0	25.5	11.0	34°
11	Right M.	24.0	15.0	12.0	22.0	24.0	20.0	31.0	14.2	17.3	11.0	41°
12	Left	23.0	14.0	13.0	23.0	23.0	22.0	33.0	17.8		12.5	43°
13	Left	18.0	10.6	10.0	18.0	18.0	17.0	31.5	16.0	26.5	11.0	38°
14	Left	17.6	10.7	10.5	22.3	17.6	18.0	27.0	10.0	15.0	9.0	45°
Mean Number		21.8	14.2	10.5	24.0	21.8	20.3	29.9	17.0	24.2	10.8	41.7

Fig. 2.



Adult (A, $^1/_2$ nat. Size) and Fœtal (B, $^2/_1$ nat. Size) Astragalus.

$a\,a^1$, Axis of rotation of articular cone.
$a^1\,a^2$, Longitudinal Axis of sustentaculum.

The oblique line (a) at right angles to which the impressions were taken, is the axis of rotation of the cone surface, this runs obliquely forwards and downwards from without in, at a mean angle with the sagittal axis of the Calcaneus of 61^0, and with the horizontal plane of $12^0.8$.

The posterior of the two impressions taken at right angles to the oblique line *(a)* will be the part of the base of the cone which lies on the facet, and from this the apex can be found, by measuring the height of the cone along the axis of rotation of the cone surface.

The apex was found in this way to fall close to the posterior edge of the Sustentaculum Tali *(a^1)*, being sometimes slightly within, that is beyond the Sustentaculum, at others slightly without, i. e. in the Sinus Tarsi.

		Angle of axis of rotation of cone surface with Sagittal axis of Calcaneus.	Angle of cone surface with Horizontal axis of Calcaneus.	Angle of axis of cone with cone surface.	Angle of axis of cone with Horizontal axis of Calcaneus.	Angle of axis of rotation on Talo-Calcan.-facet with Sagittal axis of Astragalus.	Angle of axis of rotation on Talo-Calcan. facet with transverse axis of Astragalus.
	Adult Feet.						
1	Left F.	61	14	42	28	54	31
2	Right M.	61	14	55	41	55	30
3	Left M.	67	21	42	21	55	28
4	Right F.	63	10	33	19	49	35
4	Left F.	60	7	34	27	48	34
5	Right M. 14 yrs	57	9	42	33	40	39
6	Right M.	64	13	38	25	51	36
7	Left M. 22 yrs	57	12	47	35	42	39
8	Right M.	58	15	51	36	54	36
9	Right M.	65	10	36	26	53	37
10	Left M.	62	14	56	42	44	39
11	Right M.	63	20	47	27	50	43
12	Left M.	58	11	45	34	49	34
13	Left	54	10	44	34	41	39
14	Left	68	12	37	25	52	37
Mean Number		61	12.8	43.2	29.5	49.1	35.8

			Angle of axis of rotation with line parallel with hollow of Talo-crural-facet.	
1	Right 2 yrs	66	58	31
	Fœtal Feet.			
1	Left	63	48	40
2	Right 10 mo	55	48	41
3	Right 8 mo	66	49	40
4	Left 9 mo	48	32	52
5	Right 9 mo	67	53	39
6	Right 10 mo	56	44	46
7	Right 9 mo	59	47	43
8	Right 5 mo	68	46	31
9	Left 9 mo	54	61	37
10	Right 7 mo	48	54	38
11	Left 6 mo	67	57	35
12	Right 9 mo	49	45	44
Mean Number		58.3	48.6	40.3

The axis of the cone will have the same direction with regard to the sagittal axis of the calcaneus, as the axis of rotation of the surface. Its direction as regards the horizontal axis is to be found by deducting the angle which the surface of the cone makes with the horizontal axis of the calcaneus, from the angle at the apex of the cone enclosed between its axis and periphery.

The above table gives the degrees of these angles, and from them it appears that the axis of the cone crosses the sagittal axis of the Calcaneus obliquely from the outer side, at a mean angle of 61° forwards and inwards, and 29°.5 upwards.

As the posterior facet is formed out of a segment of this cone, the movement between the Calcaneus and Talus must be a rotation round its axis, and the axis of rotation of the two bones must have the same direction as that of the axis of the cone given above, and may therefore be said to run from about the centre of the external surface of the Tuber calcis forwards, upwards, and inwards, through the Sinus Tarsi, near the posterior border of the Sustentaculum, to come out at the inner side of the neck of the Astragalus, below the facet for the internal Malleolus.

The facet on the Astragalus articulating with the posterior part of the Talo-Calcaneal joint occupies the whole inferior surface of the body; it is oval and concave in its long diameter; in the short diameter either slightly concave or convex, according to the form of the facet with which it articulates; the long diameter does not correspond with the transverse diameter of the body, but crosses it from without inwards at about an angle of 35°.

The line on this facet, which corresponds to the axis of rotation of the cone surface, passes from a point about one third from the posterior end of the outer border, to the point where the inner border joins the posterior,

forming an angle with the sagittal axis of the Astragalus of 49°.1 with the transverse axis of 35°.8.

The table of the radii of the curves taken at right angles to this line shews that as a rule the curve is not part of one circle, but two, the smallest part being the posterior end, the two facets are not therefore perfectly congruent. This want of congruence is most general when the foot is in the middle position. In pronation the anterior and outer parts of the two facets are in close contact, whilst the posterior and inner are widely separated. In supination the congruence is almost complete, only slightly failing in the posterior part.

In the adult the Tuber Calcis and Processus anterior have a common sagittal axis, which is the sagittal axis of the Calcaneus as a whole, and may be described as passing through the bone from the centre of its posterior surface, where the rough part for the insertion of the Tendo Achillis joins the smooth part over which it glides, to come out about the centre of the facet for the cuboid. This axis forms with the sagittal axis of the Astragalus an average angle of 11°.9, with the transverse axis of 96°.9. The sagittal axis of the Astragalus is so nearly parallel with the hollow of the Talo crural facet that it may be said practically to be so.

We have seen that the axis of rotation of the cone surface makes an angle with the sagittal axis of the Calcaneus of 61° with that of the Astragalus of 49°.1, and with the transverse axis of the latter of 35°.8.

Whilst the facet has a vertical angle with the horizontal plane of the bone of 41°.7, the axis of rotation crosses the facet from about the middle of its posterior and outer border, to the inner fourth of its anterior and inner border, nearly three quarters of the facet therefore falling below, and to the anterior and outer side of the axis of rotation.

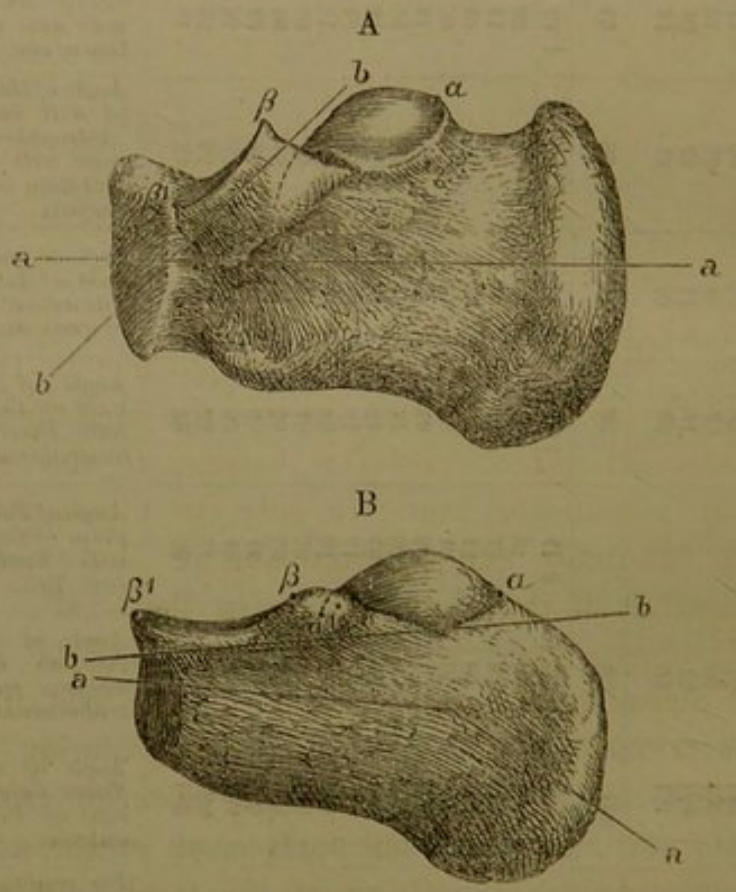
No.		Angle of Sagittal axis of Astragalus with Sagittal axis of Calcaneus.	Angle of line parallel with hollow of Astragalo-Tibial facet with Sagittal axis of Calcaneus.	Angle of Transverse axis of Astragalus with Sagittal axis of Calcaneus.	Angle of Sagittal axis of Astragalus with axis of rotation of cone surface	Angle of line parallel with hollow of Astragalo-Tibial facet with axis of rotation of cone surface.	Angle of Transverse axis of Astragalus with axis of rotation of cone surface.	Angle of Sagittal axis of Calcaneus with Direction of Sustentaculum Tali	Angle of Horizontal plane of Calcaneus with Sustentaculum Tali.	Angle of axis of rotation of cone surface with Sustentaculum Tali.	Angle of axis of Tuber Calcis with axis of Processus anterior.	Per centage lenght of line from posterior extremity of the calcis to the apex of cone calculated from the whole length of the Os calcis.
	Adult Feet.											
1	Left F.	6	6	93	54	54	31	28	50	89	180	70.0
2	Right M.	6	6	90	55	55	30	33	24	93	180	72.0
3	Left M.	12	12	94	55	55	28	32	48	94	180	62.9
4	Right F.	13	13	97	49	49	35	35	48	98	180	61.4
4	Left F.	13	13	95	48	48	34	35	50	94	180	65.2
5	Right M. 14 yrs	17	17	97	40	40	39	40	50	97	180	66.6
6	Right M.	13	13	100	51	51	36	28	37	91	180	69.5
7	Left M. 22 yrs	15	15	95	42	42	39	31	51	88	180	71.0
8	Right M.	4	4	104	54	54	36	34	48	96	180	70.8
9	Right M.	11	11	101	53	53	37	31	30	93	180	69.0
10	Left M.	18	18	102	44	44	39	40	50	103	180	71.4
11	Right M.	13	13	105	50	50	43	33	46	95	180	63.4
12	Left M.	10	10	93	49	49	34	31	43	89	180	66.8
13	Left	12	12	93	41	41	39	34	25	87	180	68.0
14	Left	16	16	105	52	52	37	31	27	98	180	69.1
	Mean Number	11.9	11.9	96.9	49.1	49.1	35.8	33.1	41.8	93.6	180	67.8
1	Right 2 yrs	20	6	96	45	58	31	26		90	180	60.9
	Fœtal Feet.											
1	Left	38	14	103	24	48	40	29		92	151	61.0
2	Right 10 mo	29	7	97	26	48	41	21		75	152	61.2
3	Right 8 mo	42	17	107	24	49	40	23		90	150	67.5
4	Left 9 mo	32	12	100	11	32	52	27		75	142	63.6
5	Right 9 mo	27	14	107	40	53	39	23		90	148	56.5
6	Right 10 mo	32	11	101	24	44	46	22		77	121	66.6
7	Right 9 mo	38	13	103	22	47	43	22		81	146	63.4
8	Right 5 mo	28	10	101	28	46	31	17		85		60.0
9	Left 9 mo	25	4	92	40	61	37	28		83	140	58.3
10	Right 7 mo	20	5	105	28	54	38	33		81	146	63.1
11	Left 6 mo	32	9	99	34	57	33	18		86	154	73.0
12	Right 9 mo	24	4	93	25	45	44	29		78	141	65.2
	Mean Number	30.5	10.0	100.6	27.1	48.6	40.3	24.3		82.7	144.6	63.2

The Sustentaculum Tali makes an average angle with the sagittal axis of the calcaneus of 33°.1, with the horizontal plane of 41.°8, with the axis of rotation of the cone of 98°.6.

In the fœtus the Tuber Calcis and Processus anterior have no common axis.

The sagittal axis of the Processus anterior must be taken as that of the whole bone. It goes from a point slightly nearer the inner border of the posterior surface than in the adult, and passes through the bone, to the middle of the facet for the cuboid; the axis for the Tuber Calcis crosses this at an angle of 144°.6 obliquely, upwards and inwards.

Fig. 3.



Adult (A, ½ nat. Size) and Fœtal (B, ²/₁ nat. Size) Calcaneus.
a. a. Sagittal axis of Tuber Calcis and Processus anterior.
b. b. Line parallel with facet on Sustentaculum Tali.
α. α¹ Extent of Talo-calcaneal facet.
β.¹ Extent of facet on Sustentaculum Tali.

The sagittal axis of the Astragalus and the hollow of the Talo-Crural facet are not parallel, as in the adult, but form an angle with each other of 21°.

The angles given on the table show that the line parallel with the hollow of the facet, has about the same relation to the sagittal axis of the Calcaneus as in the adult, and that there is no difference of importance in the angles formed by this line, the transverse axis of the Astragalus, and the sagittal axis of the Calcaneus, with that of the axis of rotation of the cone surface; but on the other hand the sagittal axis of the Astragalus makes with the last an angle of 27°.1 instead of 49°.1.

As the body of the Astragalus and its facets have the same direction in relation to the Calcaneus as in the adult, this difference in the sagittal axis of the bone will not originate in the body, but in the head and neck, which have an obliquity inwards in excess of that of the adult of about 19°.

Although the axis of rotation of the posterior facet has the same direction with the sagittal axis of the Calcaneus as in the adult, the facet itself has not, having an almost transverse and horizontal position on the Tuber Calcis. The axis of rotation crosses the facet from about the outer fifth of the posterior border, to the inner two fifths of the anterior, therefore only two fifths of the facet fall on the outer and anterior side of the axis of rotation, instead of three quarters as in the adult.

The Sustentaculum Tali has a more sagittal and horizontal direction, forming with the sagittal axis of the Calcaneus a mean angle of 24°.3. The posterior part has the same relative height with the posterior part of the axis of rotation of the cone surface, as in the adult, but from the horizontal position of the facet, not with the anterior part and rest of the facet. The posterior and inner part of the posterior facet sinks below the Sustentaculum, instead of the anterior and outer part.

The Sinus Tarsi is wider than in the adult, the Processus anterior slightly longer and higher. From its greater height, and from the Processus being directed more upwards, the facet for the head of the Astragalus on its anterior part is as high as, and in some cases higher than, the facet of the Sust. Tali and posterior facet, having also a more sagittal direction.

The cause of the change of form which takes place in the bones, is probably to be found in the different action of the muscles, inserted into the Calcaneus, before and after birth.

The usual position of the fœtus, during the last months of fœtal life is with the thighs flexed on the abdomen, legs upon thighs, and feet in dorsal flexion.

The Plantaris and the part of the Tendo Achillis formed by the Gastrocnemii having their origin from the femur are relaxed by flexion of the legs on the thighs, thus weakening the strength of the Tendo Achillis, whose resistance with that of the other plantar flexors, is overcome by the dorsal flexors which flex the foot more fully than is possible with the knee extended.

The Plantaris, Soleus and Gastrocnemius, are the only muscles arising from the leg inserted into the Calcaneus; the first is inserted into the lower and inner part of the posterior surface, the other two, forming the Tendo Achillis, occupy the whole rough part of the posterior surface. From this insertion their action on the bone would be to draw the Tuber Calcis upwards and outwards from the posterior tubercle, in this way counteracting the influence of the Flexor Brevis Digitorum, Flexor Accessorius, Abductor Pollicis Pedis and Abductor Minimi Digiti, whose origins are from the posterior tubercle and the inferior surface of the Tuber Calcis immediately in front of it.

The Flexor Brevis would be the one which would have most influence, and this cannot be separated from

the deep plantar fascia, the strong central portion of which is attached to the large posterior tubercle, to the inner part of which the Flexor itself is attached.

Abductor Pollicis has one of its origins from the inner part of the great tuberosity.

Abductor Minimi arises from the front of both posterior tubercles.

Flexor Accessorius has its larger and inner head arising from the inner surface of the Tuber Calcis, whilst its external head is attached to the plantar surface, a ittle in front of the external tubercle. No muscles are attached to the Processus anterior.

The muscles just mentioned, especially the short Flexor and the Accessorius, are extended by dorsal flexion of the foot; from their origin they tend to draw the Tuber Calcis forwards and inwards, and this tendency meeting with but slight resistence from the weakened Tendo Achillis, would cause the Tuber Calcis to be depressed in its posterior part, and the Processus anterior forced more outwards and upwards by the tension on the inner and under surface of the bone.

The different axis thus given to the Tuber Calcis. causes the horizontal and transverse position of the posterior facet; and as a consequence of the movement which this position, as we shall afterwards see, gives to the Posterior Talo-Calcaneal joint, arises the obliquity of the head and neck of the Talus, the horizontal position of its head, and the sagittal direction of the Sustentaculum Tali

The horizontal direction of the facet which articulates with the Scaphoid, gives the Scaphoid a more horizontal position, and, through it, influences the rest of the foot, the whole inner border being more raised.

After birth the foot is no longer in extreme dorsal flexion, therefore the plantar flexors and Soleus are relaxed, but at the same time extension of the knee causes the Plantaris and Gastrocnemii to be stretched, so that instead

of the Tuber Calcis being dragged forwards and inwards, it is drawn upwards, and in this way a change in its axis is gradually caused which is the easier from its being so little ossified at the time of birth.

The change of the horizontal and transverse position of the posterior facet would be further aided by the increase in height of the posterior part of the Tuber Calcis, which would raise the posterior border, and thus throw the whole facet forwards and downwards as found in the adult.

Hueter[1] has given the movement of the Talo-Tarsal joint as being that of supination and pronation, and its extent as about 40° in both adult and fœtus, saying that although supination in a fœtus is greater than in an adult, pronation is less, it being hardly possible to pronate the foot beyond the horizontal position. He considers the cause of this difference to be the absence of check to supination, from the want of development of the Sustentaculum Tali, and the early check to pronation, which the greater relative height of the Processus anterior gives. A change in these surfaces he considers to be caused by the pressure of the weight of the body in walking and standing; but, as Volkman points out, this change occurs just as well in children who are obliged to lie still during the first years of their life, so that it is not enough to account for it.

If the articulating facets of the posterior part corresponded in their whole extent to a segment of the surface of the cone, the only movement possible between them would be simple rotation to and fro over its axis, and this rotation, as the axis is more sagittal than frontal, would give a movement of adduction and abduction; but the segment only occupies a part of the facet on the Calcaneus, whilst that on the Talus is not perfectly congruent, therefore the movement is not confined to that of

[1] Klinik der Gelenkkrankheiten. Bd. II. S. 106—114.

adduction and abduction, but a further movement of the Talus is permitted, from which arises the raising and depressing of the borders of the foot, and this double movement of the Talo-Tarsal joint is best expressed by supination and pronation.

In the adult, if the anterior part of the foot is held so that no independent movement takes place in the Talo-Scaphoid, Calcaneo-Cuboid and Tarsal joints, the inner and outer borders of the foot can be but slightly raised thus showing that the movement which takes place in the Talo-Calcaneal part of the Talo-Tarsal joint, when that of the Talo-Scaphoid is excluded, is nearly confined to adduction and abduction.

In the fœtus on the other hand the borders of the foot are raised and depressed almost as freely when the movement of the anterior part is excluded, as when it is free.

The movement found in each case is given in the table; for the adult it will be noticed that it does not amount on an average to half that given by Hueter, but in the fœtus it does, being almost twice as great as was found in the adult.

This excess of movement was largely due to the increased supination, which I should explain rather by the transverse position of the Posterior facet, and the consequent altered relation of the surface of the facet to the axis of the cone, than to the want of development of the Sustentaculum Tali.

		EXTENT OF SUPINATION AND PRONATION OF ANKLE JOINT ESTIMATED IN DEGREES.		
		Talo-Calcaneous Joints.	Talo-Calcaneous and rest of foot.	Amount of Difference.
	Adult Feet.			
1	Left F. . .	15.5	20.0	4.5
2	Right M. . .	12.2	17.7	5.5
3	Left M. . .	11.5	14.0	2.5
4	Right F. . .	14.2	22.2	8.0
4	Left F. . .	12.2	20.5	8.2
5	Right M. 14 yrs.	13.7	18.7	5.0
6	Right M. . .	14.5	18.0	3.5
7	Left M. 22 yrs. .	13.5	17.7	4.2
8	Right M. . .	17.2	26.2	9.0
9	Right M. . .	15.7	20.7	5.0
10	Left M. . .	16.5	21.0	4.5
11	Right M. . .	15.5	18.5	3.0
12	Left M. . .			
13	Left . . .	10.7	15.7	5.0
14	Left . . .	12.3	17.5	5.0
15	Left . . .	11.7	15.7	4.0
	Mean Number	13.8	18.9	5.1
1	Right 2 yrs. .	15.5	18.7	3.2
	Fœtal Feet.			
1	Right . . .	29.7	32.0	2.2
2	Left 10 mo .	26.2	27.5	1.2
4	Right 9 mo .	29.7	31.5	1.7
5	Left 9 mo .	38.7	40.2	1.5
6	Right 10 mo .	37.7	41.2	3.5
6	Left 10 mo .	44.7	45.2	5.0
7	Right 9 mo .	34 7	36.0	1.2
7	Left 9 mo .	40.7	43.0	2.2
9	Right 9 mo .	28.2	30.2	2.0
9	Left 9 mo .	36.0	37.0	1.0
10	Right 7 mo .	31.7	34.0	2.2
10	Left 7 mo .	42.7	45.5	2.7
11	Right 6 mo .	39.2	40.5	1.2
11	Left 6 mo .	40.2	40.2	0.0
12	Right 9 mo .	26.2	28.5	2.2
12	Left 9 mo .	22.2	24.2	2.0
	Mean Number	34.3	36.0	1.7

ANTERIOR TALO-CALCANEOUS JOINT.

Into this part of the joint enter the facets on the Sustentaculum Tali and the Processus anterior of the Calcaneus, and their corresponding facets on the head and neck of the Talus.

The facet on the Sustentaculum is an oval with its long diameter in the sagittal direction; from side to side it is concave, from above down it varies, being sometimes slightly convex in its lower part, and concave in the upper, in other cases the convexity of the upper was stronger than in the lower, this convexity appearing to depend on the position of the apex of the cone of the posterior part, it being very marked when the apex fell on the inner side of the Sustentaculum Tali.

The facet on the Processus anterior was small and unimportant as to form.

The facet on the neck of the Talus to articulate with the Sustentaculum is concave in all directions, in its anterior part it is larger than its fellow, being widened on the outer side, so that when in pronation the Talus moves forwards and inwards on the Calcaneus, the two facets come into closer contact from this widened portion corresponding in form to the anterior and inner side of the Sustentaculum facet.

As the anterior and posterior Talo-Calcaneal joints are formed from the same two bones, they must have a common axis of rotation, and this axis has been found by the measurements of the posterior part to run through

the Calcaneus and Talus, obliquely upwards, forwards, and inwards, from the middle of the external surface of the Tuber Calcis, through the posterior part of the Sinus Tarsi, coming out on the inner surface of the neck of the Talus below the facet for the Internal Malleolus. The anterior joint lies almost entirely to the outside of this axis of rotation; it cannot therefore be formed from a second cone of the same size as the first, as this would not allow for as much movement as it possesses, but it may be part of a larger cone. In this way the two parts do not form a regular double joint, but the anterior forms a lateral arm secondary to the posterior part.

In the fœtus, from the more sagittal direction of the Sustentaculum Tali, the secondary cone is smaller than in the adult, so that the difference between the size of the two cones is not so great.

TALO-NAVICULAR JOINT.

This joint is formed by the head of the Talus and the hollow cuplike facet which receives it on the Scaphoid.

The facet on the head of the Talus is said by Ludwig [1] and Aeby [2] to be part of the surface of a sphere.

Henke [3] and Henle [4] describe the head as not perfectly round, as the curve of the transverse diameter is as a rule larger than that of the vertical.

Hueter [5] gives the head as part of a ball with its centre in the neck, but deviating in some parts from a perfectly round form, he also says that the oval for the Scaphoid in the fœtus has an almost horizontal position, whilst in the adult it has an obliquity downwards from the outer side of about 45°.

The facet on the Talus is oval and convex in both diameters, and is lengthened on the inner side by the part over which the inferior Calcaneo-Scaphoid Ligament glides. The radii given in the following table are of the curves of the long and short diameters of the facet which articulates with the Scaphoid, that with the ligament not being included.

[1] Physiologie des Menschen. 1858. Bd. I. S. 528.
[2] Der Bau des menschlichen Körpers. 1871. S. 325.
[3] Anatomie und Mechanik der Gelenke. 1863. S. 258.
[4] Anatomie des Menschen. 1855. Bd. I. Theil 2. S. 159.
[5] Klinik der Gelenkkrankheiten. 1877. Bd. II. S. 114.

		RADII IN mm OF DIAMETERS OF ASTRAGALO-SCAPHOID FACET.					Angle of long diameter of Astragalo Scaphoid facet with the horizontal plane of Astragalus.
		Facet on Astragalus.			Facet on Scaphoid.		
		Long diameter.	*Short diameter.*	*Per centage value of short diameter with long diam. as 100.*	*Long diameter.*	*Short diameter.*	
	Adult Feet.						
1	Left F.	20.0	15.0	75.0	21.2	17.8	40
2	Right M.	22.0	15.0	68.1	22.0	18.8	37
3	Left M.	19.0	15.0	78.9	16.5	16.0	44
4	Right F.	19.0	13.5	71.1	18.0	14.0	45
4	Left F.	19.0	13.0	68.4	18.8	15.2	35
5	Rt M. 14 yrs	18.6	12.0	66.6	18.0	16.0	29
6	Right M.	21.2	17.0	80.9	21.5	16.5	47
7	Lt M. 22 yrs	17.0	11.0	64.7	20.8	13.5	43
8	Right M.	17.0	11.0	64.7	17.2	13.0	48
9	Right M.	18.0	14.0	77.7	20.8	22.5	36
10	Left M.	20.0	16.0	80.0			47
11	Right M.	19.0	14.0	73.6	20.0	16.5	45
12	Left M.	21.0	16.0	76.1	22.6	17.0	52
13	Left	19.0	17.0	89.4	22.0	19.0	38
14	Left	21.0	16.0	76.1			42
Mean Number		19.3	14.3	74.7	19.7	16.6	41.8
1	Right 2 yrs	14	10	71.4			25
	Fœtal Feet.						
1	Right	4.8	4.8	100			Horizontal
1	Left						Horizontal
2	Right 10 mo	7.6	6.5	85.0			11
3	Right 8 mo	6.0	6.0	100			12
4	Left 9 mo	6.0	5.5	91.6			Horizontal
5	Right 9 mo	6.0	6.0	100			Horizontal
6	Left 10 mo	5.7	5.7	100			13
7	Right 9 mo	5.7	5.7	100			23
8	Right 5 mo						5
9	Left 9 mo	7.0	6.0	85.7			20
10	Right 7 mo	4.7	4.7	100			13
11	Left 6 mo						12
12	Right 9 mo	6.0	5.8	96.6			20
Mean Number		5.9	5.6	95.8			10.0

It will be seen that in the adult the radius of the short diameter averaged only 74.7 per cent of that of the long, the facet is therefore part of a spheroid or elipsoid, and not part of a perfect sphere.

But in the fœtus it may be called a sphere, as frequently the two diameters were the same, and the average difference only amounted to 4.2 per cent, and this is in accordance with the change which Aeby[1] has shown generally takes place in the shoulder and hip joints of man and other mammalia; in the fœtus their form is that of a perfect sphere, but with growth this regularity of form is gradually lost, until in the adult it is no longer a sphere but a spheroid or elipsoid.

The facet of the adult has an obliquely transverse position on the head of the Talus, its outer part lying higher than the inner, the long diameter passing from the upper outer part, to the lower and inner, at an average angle with the horizontal plane of the bone of $41^0.8$.

In the fœtus, as Hueter has said, the facet is almost horizontal, the long diameter making an average angle of only 10^0 with the horizontal plane.

The point of rotation will be found from the radii of the diameters. The long diameter in the adult has an average radius of 19.3^{mm}, the short of 14.3^{mm}. In the fœtus the two are so nearly alike, that that of the long, 5.3^{mm}, may be taken for both.

These radii place the point of rotation in about the centre of the neck, and a line drawn from the centre of the surface of the facet, i. e. where the long and short diameters cross each other at right angles, through this point of rotation, has a course parallel with the sagittal axis of the Talus, from which it follows that the axis of rotation of the Talo-Scaphoid part of the Talo-Tarsal joint

[1] Beiträge zur Kenntniss der Gelenke. Deutsche Zeitschrift für Chirurgie. Bd. VI.

will cut that of the Talo-Calcaneous at an angle of 49°.1 in the adult, and 27.1 in the fœtus.

The point of rotation of the Talo-Scaphoid joint is therefore eccentric in both cases to that of the Talo-Calcaneous, but this eccentricity is only half as great in the fœtus as in the adult, and as the amount of supination and pronation in the Talo-Scaphoid joint depends upon the eccentricity of its point of rotation, the greater eccentricity explains why in the adult almost the whole amount of supination and pronation can take place as a secondary movement in this part of the joint, instead of being, as in the fœtus, part of the primary movement of the Talo-Calcaneous joint.

As further evidence that the point of rotation has this position in the neck of the Talus, it may be mentioned that a point of rest, which in movement of the Talo-Tarsal joint is found in about the middle of the superior and inner surfaces of the neck, near the edge of the facet for the Scaphoid, corresponds to the point at which a line from the point of rotation, perpendicular to the axis of rotation, would leave the bone.

In conclusion the points of difference between the adult and fœtus may be given shortly as consisting in the Calcaneus, of the different sagittal axis of the Tuber Calcis, and the want of development of its posterior part, from which arises the transverse and horizontal position of the posterior facet, the more sagittal direction of the Sustentaculum Tali, and the greater proportional height of the Processus anterior. In the Astragalus, in the greater obliquity of the head and neck, which causes the sagittal axis of the bone to differ from the line parallel with the depression of the Talo-Crural facet, and in the globular form of its head, and the horizontal direction of the long diameter of the facet upon it for the Scaphoid.

The fact that the transverse and horizontal position of the posterior facet allows the raising and depressing of

the sides of the foot to take place in the fœtus in the primary joint, instead of as in the adult principally in the secondary, explains the horizontal position of the facet for the Scaphoid, there being no occasion for supination and pronation to be increased by aid of the movements of the anterior part of the joint.

But when the position of the posterior facet is changed by the gradual development of the Tuber Calcis, the free supination and pronation of the primary joint is lost, but is compensated in part by increased movement in the Talo-Scaphoid joint, which is permitted by the greater eccentricy of its point of rotation, and obliquity of direction of the long diameter of the facet for the Scaphoid, the change in the form of the head arising at the same time.

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