PARABOLAS AND FOOT FUNCTION

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The relationships of the metatarsal heads determine how the metatarsophalangeal joints will serve the functions of plantigrade, digitigrade and unguligrade stance, gait, support and reach.

A line drawn through the metatarsal heads forms a parabola – an unequal curve (1). This is due to the fact that in the great majority of feet the second metatarsal is the longest (Wood Jones, 1944). The first metatarsal is usually shorter so that it can plantarflex to allow the hallux to dorsiflex in normal forefoot function. The medial parabola is delineated by a transverse axis (a line drawn through 1st and 2nd met heads (2). Laterally, the parabola defines an oblique axis (a line drawn through the lesser metatarsal heads (3).

Finn Bojsen-Møller, a Scandinavian Professor of Anatomy who has written extensively upon the function of the foot, has examined these axes and the reconfiguration that occurs within the foot skeleton upon selection of each axis. He pointed out that behind each metatarsal axis the foot skeleton forms a resistance (lever) arm at right-angles to the axis, and that the transverse axis lever arm is approximately 20% longer than the oblique axis lever arm. At the end of the longest lever arm is the largest metatarsal head, with two associated sesamoids bones to further increase the diameter around which the plantar fascia is wound. This creates a 'high gear' mechanism for control of the medial foot. The smaller diameter of the lesser metatarsal heads and the shorter lever arm formed behind them has less winding effect upon the plantar fascia, a 'low gear' mechanism that works more centrally in the foot.

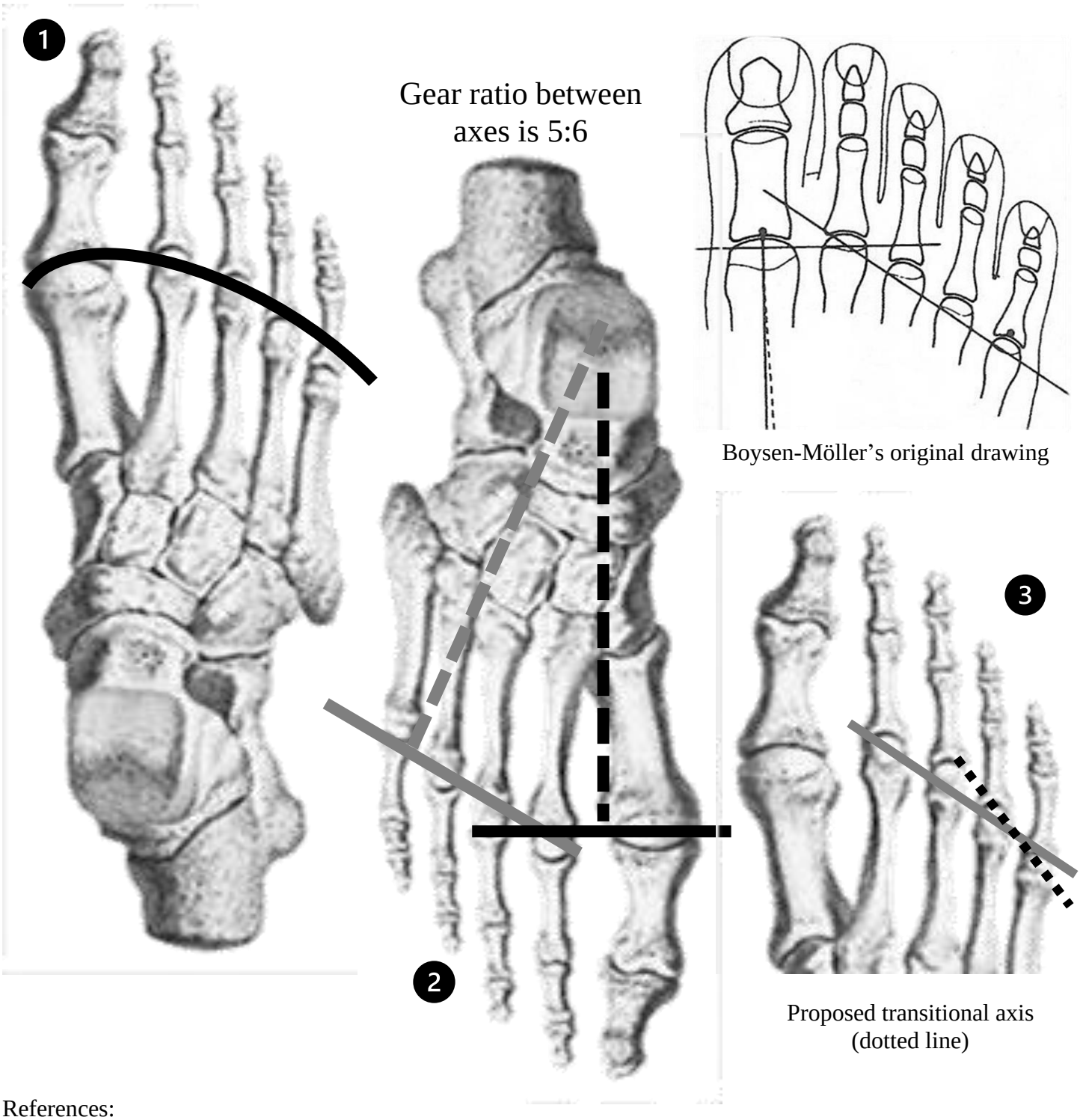
In gait, and in standing on the toes to look over a high wall, the transverse high gear axis is selected because the longer lever arm allows longest stride and raises the body highest. Here, the tibia is kept straight, the talus and calcaneum are aligned with the transverse axis lever arm, the ***peroneus longus*** pronates the foot over the transverse axis, the first metatarsal is plantarflexed, the hallux dorsiflexed, and the plantar fascia is wound around the first metatarsal head to stabilise the foot. The plantar fascia is hard, prominent and visible on the plantar aspect and the peroneus longus can be seen contracted on the lateral aspect of the leg and foot.

When navigating an unequal surface, in climbing or reaching to the side, we might engage the low gear oblique axis. The tibia is then rotated externally, abducting the talus so that it aligns with the oblique axis lever arm, raising the foot onto the lesser metatarsal heads. In this configuration, the foot is stabilised by close congruence of the calcaneocuboid joint. The foot is supinated over the oblique axis and the first metatarsal and hallux are plantarflexed by ***flexor hallucis longus*** to give stability. The medial longitudinal arch appears raised, but this is due to the 1st ray plantarflexion and the calcaneal inversion. The plantar fascia here serves to plantarflex the toe pulps to the ground for unguligrade function and proprioception. The plantar fascia in this mode is not made prominent, tense or palpable on the plantar aspect.

In normal feet (the pattern most often encountered), the fifth metatarsal head is set back proximally from the line of the oblique axis. Although the physical length of the 5th metatarsal may actually equate to the length of the 4th metatarsal, its effective length is reduced by the relationship of the bases of these bones with the supporting cuboid, and the 5th metatarsal head remains free of ground contact in both digitigrade states. Just as we indicated the transverse and oblique axes by drawing lines through the metatarsal heads, we can draw a line through the 4th and 5th metatarsal heads which is not contiguous with the oblique axis (3) dotted line. Since the author can find no reference to the existence of this third axis in the literature, it is referred to here as the ***transitional axis*** in recognition of its mechanical initiation and facilitation of transfer of the bodyweight from lateral to medial forefoot in gait, as demonstrated by the superimposition of the centre of pressure line. Note that the centre of pressure line runs proximally and medially to the 5th metatarsal head and that medial transfer is initiated before the 5th met head is loaded. However, the effect of the transitional axis is well understood and the understanding is frequently utilised in orthotic shell design and parabola reconstruction surgery where osteotomy may be performed to shorten a long or plantarflexed metatarsal. The transitional axis is separate and distinct in its presentation and mode of action, and fully justifies recognition as a third definable part of the metatarsal parabola.

If we superimpose the centre of pressure line we can see how it relates to the plantar fascia

… and the skeleton



Boysen-Möller's original drawing

Proposed transitional axis
(dotted line)

References:

Bojsen-Møller F, (1979) Calcaneocuboid joint and stability of the longitudinal arch of the foot at high and low gear push off *J.Anat* **129**, 1, pp 165-176

Bojsen-Møller F, Lamoreux L. (1979) Significance of free dorsiflexion of the toes in walking. *Acta orthop.scand.* 50, 471-479

Hicks JH. (1954) The mechanics of the foot: II. The plantar aponeurosis and the arch, *Journal of Anatomy* Vol.88, Part 1

Wood Jones F. (1944) *Structure and function as seen in the foot,* pp 1-134, Bailliaire, Tindal and Cox, London.

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Your responses should be submitted on A4 paper and should be of sufficient length to demonstrate your understanding of the topic. Each answer requires a short essay (typically 500 words or ½ page A4).

Task 1
Describe the transverse axis – how does it function in human movement?

Task 2
Describe the oblique axis – how does it function in human movement?

Task 3
Explain the terms 'high gear' and 'low gear' when relating to the foot axes.

Task4
Describe the proposed 'transitional axis'.

Task 5
How does the transitional axis relate to human movement?

Please sign the following declaration and submit it with your response:

"I certify that the work that I have submitted is my own original work, and that any previous work that I have drawn upon has been given due credit by showing reference to that work"

Signature: ……..

Please credit the Alliance with the administration fee (£25) and send your answers to:

CPD Dept, The College of Foot Health Practitioners, Parkside House, Oldbury Road, Blackheath, B65 0LG

A CPD certificate will be issued for 10 CPD points on successful completion.

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