Exposing the Myths about Metatarsalgia

Recent studies provide the truth about the etiology of this common condition.

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Despite its prevalence, metatarsalgia remains one of the most poorly understood and often mistreated disorders of the human foot. The term metatarsalgia is commonly used to describe pain on the plantar aspect of the forefoot.[1,2] The lesser metatarsal region of the forefoot is the most common location of foot pain in older people. An examination of 784 community-based adults aged 65 and older revealed that 37% had pain to palpation of the forefoot, with pain divided equally between the metatarsal heads and the intermetatarsal spaces.[3] In comparison, plantar heel pain was found in only 11% of this same group of older adults.[3]

Metatarsalgia is a descriptive term and not a specific diagnosis. A study by Scranton, reporting on 98 patients presenting with metatarsalgia, revealed twenty-three different diagnoses accounting for pain in the forefoot.[4] These diagnoses included: Morton's neuroma, plantar plate pathology, stress fracture, avascular necrosis/Freiberg's disease, brachymetatarsia, benign skin lesion, bursitis, tendinitis, capsulitis, and arthritis. Most authorities equate the term metatarsalgia to "central metatarsalgia" describing pain in the forefoot, excluding disorders to the 1st and 5th MTPJ.[5] The two most common accepted causes of this overload causing primary metatarsalgia are long central metatarsals or plantarflexed central metatarsals.[5] However,

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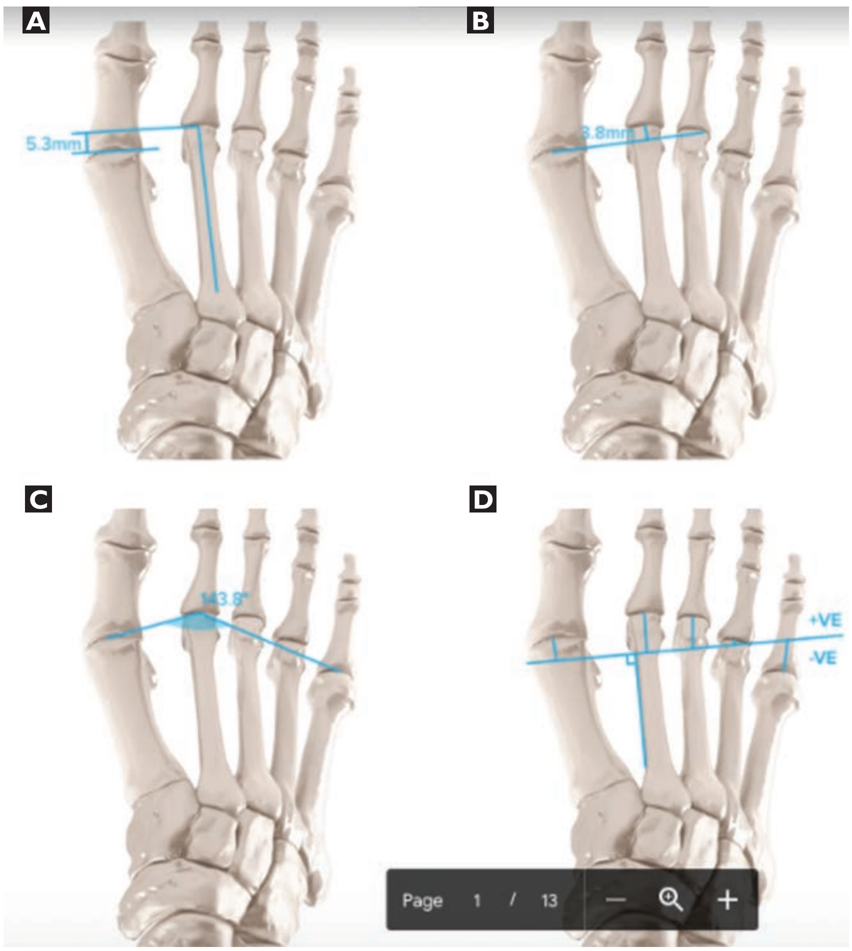


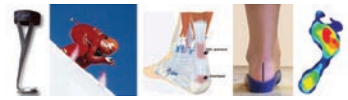
Figure 1: Methods of measuring relative lengths of the metatarsals which do not account for distortion from HAV deformity.

(A) The metatarsal protrusion index as described by Nilsonne takes into account only the relative lengths of the first and second metatarsals.

(B) The metatarsal protrusion distance as described by Coughlin considers the relative lengths of the first, second, and third metatarsals.

(C) Meschan's metatarsal break angle describes the angle created by connecting the distal most aspects of the first, second, and fifth metatarsals.

(D) Maestro's method uses a transmetatarsal line which is perpendicular to the medial border of the second metatarsal and centered in the lateral sesamoid.



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further scrutiny of published research will cause doubt about this cause-effect relationship.

The Myth of Elongated Metatarsals Causing Metatarsalgia

One of the biggest misconceptions in foot and ankle surgery is the role of elongated metatarsals causing metatarsalgia. Clinicians have long assumed that "elongated metatarsals" create increased plantar pressure, which then leads to pain and injury to structures around the metatarsal heads. This myth continues to be propagated despite published research with contradictory findings.

Fundamental to this issue is the method of measuring length of the metatarsals based upon standing A/P radiographs (Figure 1). Most techniques use a line drawn across the apex of the metatarsals but fail to take into the account that an increased intermetatarsal angle in hallux abductovalgus (HAV) deformity will distort the measurement. Deviation of the first metatarsal in a medial direction, away from the second metatarsal as seen in HAV deformity, will automatically shorten its position from the transverse axis of the second and third metatarsals. However, the actual length of the first metatarsal has not changed.

To account for the effects of angulation of the first metatarsal relative to the second metatarsal, Hardy and Clapham developed a technique which uses a compass to draw an arc around the distal margins of the metatarsals on an A/P radiograph (Figure 2).[8] With this method, a true parabola is drawn and relative elongation of one or more metatarsals can be determined regardless of deviation of the first metatarsal in a medial direction. Since almost half of patients with metatarsalgia also have HAV deformity[3], it is easy to see why studies of metatarsal length which do not use the Hardy and Clapham method will automatically conclude that a short first metatarsal is a primary etiology of central metatarsalgia. However, we will see that more recent quality studies have refuted that notion.

HARDY CLAMPHAM MEASUREMENT

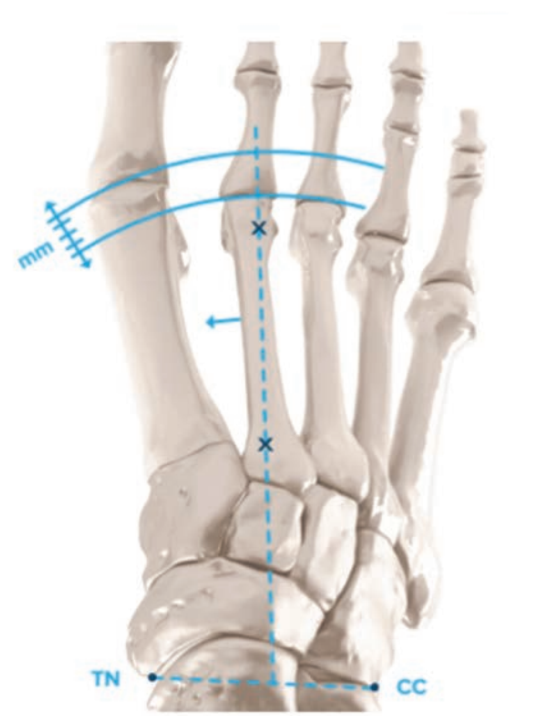

Figure 2: Using a compass, two arcs are drawn: one at the distal extent of the articular surface of the first metatarsal and one at distal extent of the articular surface of the second metatarsal. A perpendicular line drawn between the two arcs is measured in millimeters, with a positive value indicating a second metatarsal that is relatively longer than the first. A similar perpendicular line is drawn from the midpoint of the head of the third metatarsal to the arc of the first metatarsal.

One of the few studies focusing on primary metatarsalgia and radiographic measurements was published by Slullitel and co-workers.[6] All of the 121 subjects in this study had HAV deformity, and 45% of them also had symptoms of metatarsalgia. Using the Hardy Clapham method, ***abnormal metatarsal length had no statistical correlation with incidence of metatarsalgia.*** In fact, patients with a minus index (i.e., short first metatarsal) were less likely to have metatarsalgia. Also, the magnitude of HAV deformity measured by the hallux abductus angle and intermetatarsal angle was not correlated with incidence of metatarsalgia. Metatarsalgia was associated with increased age, increased body weight, gastrocnemius contracture, and presence of digital deformity.[6]

Elongated metatarsals have been associated with digital deformities, particularly crossover toe and plantar plate injuries.[7-10] With little proof, several authors have speculated that elongated metatarsals will increase plantar pressure which leads to attrition and eventual rupture of the plantar plate.[9,10] However, scrutiny of the medical literature on this subject shows conflicting evidence linking elongated metatarsals to plantar plate injury.

Katz and Coughlin use the term "crossover toe" to essentially describe a plantar plate tear, since the majority of patients in their study had a positive drawer test consistent with this injury.[11] In this study of 169 patients with crossover toe deformity, less than half (44%) had an elongated second metatarsal. In fact, among all patients in this study, the overall length of the second metatarsal was 0.2mm less than the first metatarsal.

Abnormal plantar pressure has been attributed to be a primary mechanical force causing metatarsalgia.[12] This is validated, to some degree, with studies showing that interventions which reduce plantar pressure under the metatarsals im-

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The proposal that a plantarflexed metatarsal, rather than an elongated metatarsal is a contributor to metatarsalgia was supported by Jung, et al.

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prove the symptoms of metatarsalgia.[13,14] In static stance, metatarsal length would have less influence on plantar pressure than during terminal stance and pre-swing when weight is shifted to the forefoot. However, metatarsal length has no influence on plantar pressure, according to several studies.

Dreeben studied thirty-seven patients (45 feet) with primary metatarsalgia under the second metatarsal head.[15] The contralateral symptom-free feet of the patients were used as controls. Metatarsal length and height of the metatarsal head from the supportive surface were measured and then correlated with plantar pressure measurements obtained from a pedobarograph. ***In this study, plantar pressure did not correlate with metatarsal length, but did closely correlate with metatarsal head position or height from the ground.*** When a second metatarsal osteotomy was performed, decrease in plantar pressure occurred when the metatarsal head was elevated, while shortening of the metatarsal had minimal effect on plantar pressure. In order to reduce plantar pressure and pain, the second metatarsal head required elevation by at least 3.5 mm; however, the reduction in plantar pressure was not predictable with the amount of elevation. Decreased plantar pressure was noted under the first metatarsal in patients with metatarsalgia. The authors concluded that plantar pressure under the metatarsal heads is multifactorial and might be affected by the quality of the soft tissues and plantar fat pad.

Loss of stability of the first ray during dynamic gait may be the most significant factor causing central metatarsalgia.

The proposal that a plantarflexed metatarsal, rather than an elongated metatarsal, is a contributor to metatarsalgia was supported by Jung, et al.[16] In this cadaver study, osteotomies were performed on the first metatarsal to determine the effect of dorsal elevation versus shortening of the bone on plantar pressure. Dorsal elevation had a greater effect on reducing pressure under the first metatarsal than shortening. Both dorsal elevation and shortening of the first metatarsal caused significant increased plantar pressure under the second metatarsal. It should be noted that studies of metatarsal elevation involved osteotomies on cadavers and there is little evidence that an intact foot can have a plantarflexed or dorsiflexed metatarsal causing metatarsalgia. This condition seems much more likely to occur after surgical procedures involving osteotomy of one or more metatarsals.

Kaipel and co-workers prospectively studied 46 patients with metatarsalgia compared to 45 asymptomatic patients and used radiographic and pedobarographic measures to determine the role of metatarsal length and plan-

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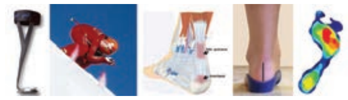

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tar pressures in causing symptoms of metatarsalgia.[17] These researchers used a simple linear reference from the head of the second metatarsal, extending across to the first and third metatarsals to measure relative length of the bones. As shown previously, a deviated first metatarsal can alter this measurement. This probably was not a factor, as patients with HAV deformity were excluded from the Kaipel study. ***The relative lengths of the metatarsals did not correlate with the pressure or force under the respective metatarsal.*** Also, there was no difference in peak pressure under the central metatarsals comparing the group with metatarsalgia with the control group. There were no differences in metatarsal length patterns when comparing the groups with metatarsalgia to those without metatarsalgia. The only significant finding was a decrease in peak force under the first metatarsal in the metatarsalgia group, similar to what was found in the study by Dreeben, et al.[15] This validates a long-accepted notion that instability of the first ray is the primary cause of metatarsalgia.

To summarize, studies do not support the notion that elongated metatarsals increase plantar pressures or cause an increased incidence of metatarsalgia. Instead, the sagittal plane position of the metatarsal appears to play a more important role in plantar pressure. This relative position of the heads of the metatarsals in the sagittal plane is important during terminal stance and pre-swing when plantar pressures peak in the forefoot. During these phases of gait, load should be shifting medially to the first ray. Therefore, loss of stability of the first ray during dynamic gait may be the most significant factor causing central metatarsalgia.

Central Metatarsalgia: The Role of the First Ray

Coughlin and Jones have published the most comprehensive study of patients with hallux valgus and did find a significant incidence of metatarsalgia which was found in 48% of patients with HAV deformity.[18] Yet, only 11% of all patients with HAV in this study demonstrated plantar callosities in the forefoot. Interestingly, metatarsalgia was the primary reason for patients to seek surgery for HAV deformity in the Coughlin study.

Improvement of the load-bearing capacity of the first ray after HAV surgery can address a primary cause of central metatarsalgia.

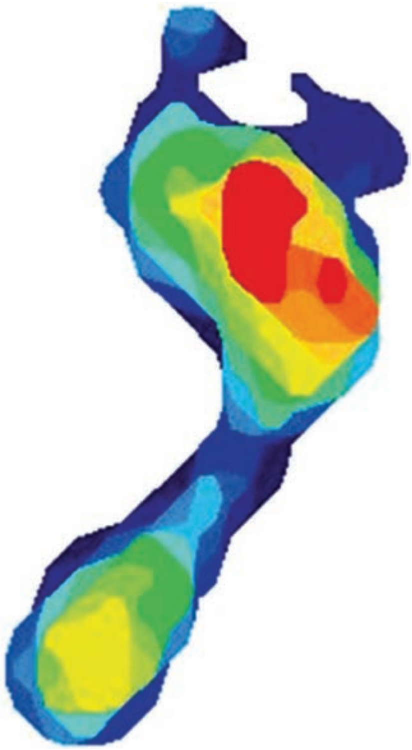

Figure 3: Claw toes predictably increase plantar pressure under the central metatarsals.

Hypermobility or instability of the first ray has been speculated to cause metatarsalgia due to a lateral shift of pressure away from the first metatarsal to the adjacent metatarsals.[19] This lateral shift of load in the forefoot has been speculated to cause synovitis of the lesser MTPs, plantar plate injury, neuroma, and metatarsal stress fracture.[20-22]

The concept of first ray hypermobility and its association with HAV has been discussed extensively by the author in a previous article published in *Podiatry Management.*[23] Hypermobility appears to be the *result,* rather than the *cause,* of HAV deformity. Hypermobility of the first ray in the sagittal plane seems to occur only when the first metatarsal shifts medially from the sesamoid envelope and loses the stabilizing effects of the plantar aponeurosis and flexor hallucis longus. This excessive dorsal mobility of the first ray measured by static exam in HAV deformity is reduced with realignment osteotomy of the first metatarsal.[24,25]

Griesberg, et al. measured first ray translation and elevation and correlated the findings in patients with various foot disorders.[26] Increased mobility of the first ray was most likely found in patients with hallux valgus and patients with metatarsalgia. However, the authors did not separate the two patient groups and the statistics suggest that most patients with metatarsalgia also had hallux valgus. Thus far, there are no published studies which show that hypermobility of the first ray is directly linked to metatarsalgia in any patient group other than those with hallux valgus.

In conclusion, there is a strong association between HAV deformity and metatarsalgia. Improvement of the load-bearing capacity of the first ray after HAV surgery can address a primary cause of central metatarsalgia.[23-25]

Role of Digital Deformity and Metatarsalgia

Bojsen-Moller and Flagstad were the first to describe a mechanism whereby extension of the metatarsal-phalangeal joint, as seen in hammertoe deformity, will cause the protective fat pad to displace distally in the foot.[27] This notion has been further verified in studies by Bus and co-workers. Their first investigation was an MRI study of diabetic patients with hammertoe or claw toe deformity, which revealed a significant anterior displacement of the

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plantar fat pad away from the weight-bearing surface of the metatarsal head.[28] This resulted in diffuse thinning of the sub-metatarsal fat pad, which would explain increased plantar pressure in this location. In a follow-up study, Bus and co-workers found that claw toe deformity caused decreased fat pad thickness under the affected metatarsal, which caused increased peak plantar pressure by almost two-fold at that location.[29] These authors propose a "fat pad-plantar pressure exchange principle" whereby the fat pad migrates distally and plantar pressure increases proximally.

In claw toes and hammertoes, significant change occurs, which compromises the plantarflexion moment of key muscles which normally stabilize the lesser digit.[30] With both plantar plate tears and with claw toes, there is significant loss of plantar purchase of the toe. Proper purchase of the digits against the supportive surface will reduce plantar pressure under the heads of the metatarsals.

Digital deformity can be expected to cause elevated plantar pressures under the central metatarsals more predictably than HAV deformity

Studies have shown that the plantar fascia provides both passive and dynamic stabilization of the digits, which offloads bending moments from ground reaction forces at the metatarsal heads.[31,32] Similar shielding of the lesser metatarsals is provided by the flexor digitorum longus which stabilizes the digits against the ground and helps disperse plantar pressure.[33]

Pressure Studies of Digital Deformities

Digital deformity can be expected to cause elevated plantar pressures under the central metatarsals more predictably than HAV deformity (Figure 3).[34] Two studies showed that claw toes or hammertoes will cause lower hallux pressures but higher central metatarsal pressures.[35,36]

High plantar pressures in diabetic patients are greatly exacerbated by digital deformities. Bus and co-workers showed that both peak plantar pressure and pressure-time integrals were significantly increased in diabetic patients with claw toe deformities compared to age- and gender-matched diabetic patients without toe deformities.[29] Digital deformities are a significant risk factor for diabetic foot ulcerations.[37] In a study of 92 patients with diabetes, Holewski found that hammertoe deformities were present in 82% of patients with a history of ulceration and amputation, while these deformities were only found in only 23% of patients who had no history of ulceration.[38]

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An important plantar pressure study was conducted by Menz and co-workers with several findings which verified previous studies of patients with metatarsalgia.[39] They studied 43 older patients with forefoot pain, measuring plantar pressures as well as metatarsal length pattern on standing A/P radiographs and then compared the results to seventy-five patients with no forefoot pain. As seen with previous studies, there was no correlation between metatarsal length and prevalence of forefoot pain, and metatarsal length did not predict increased plantar pressure. There was a higher prevalence of HAV deformity in the metatarsalgia group, but not a higher incidence of digital deformity compared to the asymptomatic group. The authors speculated that increased stiffness of the digits and plantar fat pad, without digital deformity might cause elevated plantar pressures, but most likely the lateral shift of pressure would be influenced by the larger number of HAV patients.

In conclusion, patients with digital deformity commonly complain of metatarsalgia. Digital deformities will elevate plantar pressure under the central metatarsals, especially when the plantar fat pad migrates distally. Studies are needed to verify whether surgical correction of digital deformity can relieve metatarsalgia.

Digital deformities will elevate plantar pressure under the central metatarsals, especially when the plantar fat pad migrates distally.

Summary

1) Elongated metatarsals do not cause metatarsalgia.

2) Plantarflexed or dorsiflexed metatarsals may cause metatarsalgia.

3) A significant proportion of patients with HAV deformity have metatarsalgia.

4) Digital deformities cause anterior migration of the plantar fat pad and increased plantar pressures, which can contribute to metatarsalgia.

5) More studies are needed to determine the efficacy of digital surgery or HAV surgery to relieve the symptoms of metatarsalgia. **PM**

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