JIFAF The Journal of the International Foot & Ankle Foundation
internationalfootankle.org/journal

Is there radiographic remodeling of the metatarsals in hallux valgus and pes planus?

Rajesh Botchu[1], Amer Iqbal[1], Emer McLoughlin[1], Shekhar Kalia[1], Steven James[1]

1 - Royal Orthopedic Hospital, Birmingham, UK

Foot conditions such as hallux valgus and pes planus cause altered load across the metatarsals. We performed a retrospective review of 98 patients who had foot radiographs performed at our institution for forefoot pain. The patients were divided into two groups based on their age and whether they had normal or altered foot alignment. We found that there is a mild increase in the intramedullary thickness of the third metatarsal in patients with hallux valgus (HV) and HV with pes planus (PP), which we postulate to be due to altered biomechanics and relative decrease in load on the third metatarsal.

Keywords: bone remodeling, metatarsal, hallux, valgus, pes planus

Forefoot pain, also known as metatarsalgia (MTG), refers to pain in the region of the metatarsal heads and is a common presentation in the orthopedic setting. The differential diagnosis for MTG is wide and includes trauma, disorders of the metatarsophalangeal joint, inflammatory and infectious conditions, bone and soft tissue tumors, and foot deformities leading to weight bearing alterations of the forefoot such as hallux valgus (HV) and pes planus (PP). Altered weight bearing of the metatarsal occurs in conditions such as HV and PP and this can result in stress fractures of the lesser metatarsals. In our institution, we have encountered a number of stress fractures involving the second metatarsal in patients with HV and PP, however, in our experience, stress response of the third and fourth metatarsals in the setting of HV and PP is rarely seen.

The aim of this study was to assess whether there are radiographic changes to the third and fourth metatarsals in patients with HV and PP and whether the age of the patient has any relevance to these changes.

Material and methods

A search was performed using our Computerized Radiology Information System (CRIS) to identify all the patients who had foot radiographs performed at our institution between March 2017 and March 2018. A total of 1,510 patients were identified. Following application of exclusion criteria (i.e patients presenting with trauma, infection, tumor and post-operative assessment), 98 patients presenting with forefoot pain were identified.

Patients were divided into two groups based on their age: Group 1 included 26 patients aged less than 50 years and Group 2 consisted of 72 patients aged over 50 years. The foot radiographs were reviewed, and patients were categorized on the basis of foot alignment into normal, HV (increased metatarsophalangeal angle), PP (decreased calcaneal pitch) and HV with PP.

The shaft width (ST), medial cortical thickness (MCT) and intramedullary thickness (IMT) of the second, third and fourth metatarsals were calculated at the mid-diaphysis (Figures 1 and 2). The data was analyzed using ANOVA using SPSS (released 2016, version 24.0; IBM SPSS Statistics for Mac, Armonk, NY, USA).

Results

Demographics

Out of a total of ninety-eight patients, seventy were female (71.4%) and twenty-eight (28.6%) were male. The mean age of the cohort was forty-nine years (range: 16-92 years).

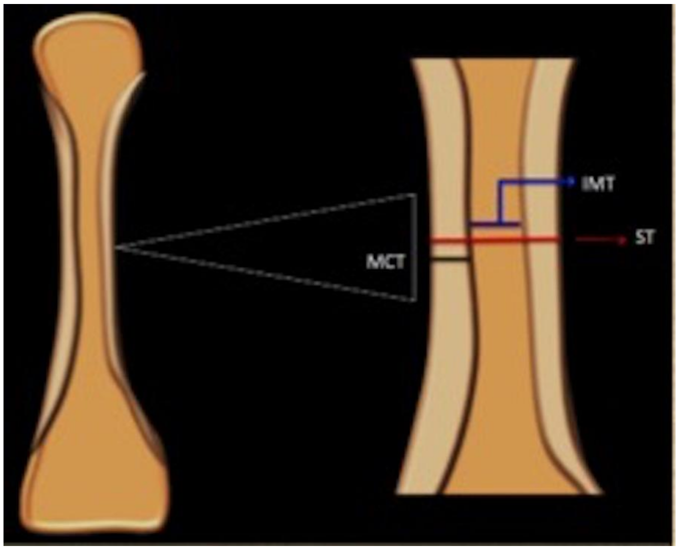

Figure 1 Diagrammatic representation of the metatarsal demonstrating measurement of shaft width (ST), intramedullary thickness (IMT) and medial cortical thickness (MCT).

Alignment

The patients were split into two groups based on their age and further categorized according to their foot alignment (Tables 1 and 2). There was a significant proportion of HV and PP identified in the patients greater than 50 years of age when compared to the younger cohort.

Remodelling

A statistically significant increase in the IMT of the third metatarsal was noted in the patients with HV and PP when compared to the patients with normal foot biomechanics (p value <0.05). The increase in IMT was more pronounced in the patients over 50 years.

No significant change in IMT was identified in the fourth metatarsal.

Discussion

Metatarsalgia (MTG) is defined as pain 'around the head of the metatarsal or metatarsophalangeal joint and adjacent soft tissue structures' [1]. The metatarsal heads bear approximately 50% of the body weight in the final stage of forefoot contact with the ground during walking [2]. In the normal population, the load acting on the first metatarsal is greater than the load on the second to fifth metatarsals [3].

Figure 2 Diagrammatic representation of metatarsal (a), anteroposterior view of foot (b) and magnified view (c) showing shaft thickness (green arrow), intramedullary thickness (yellow) and medial cortical thickness (red). Medial cortical thickening of the second metatarsal is shown by arrow (pink).

Alteration of normal alignment of foot alters the loading across the metatarsals. In patients with HV deformities, Hutton and Dhanendron found that there is increased loading through the second to fifth metatarsals and a decreased load through the first metatarsal during walking when compared to a foot with normal alignment [4]. Patients with PP deformity have a higher incidence of metatarsal stress fractures and that this is likely due to load bearing alterations to the metatarsals during the stance phase of walking [5].

It has also been shown that any painful pathology affecting the first ray especially the first metatarsal and big toe will result in increased load on the second and third metatarsals [6].

	2nd MCT	2nd IMT	2nd ST	3rd MCT	3rd IMT	3rd ST	4th MCT	4th IMT	4th ST
NORMAL (3M,4F)	2.94	3.43	8.50	2.41	3.30	7.16	2.01	3.69	7.15
HV (2M,7F)	2.70	4.10	8.65	2.20	3.79	7.26	1.83	4.09	7.20
HV AND PES PLANUS (1M,3F)	2.70	4.10	8.65	2.20	3.79	7.26	1.83	4.09	7.20
PES PLANUS (4M,2F)	3.32	3.48	9.33	2.48	3.43	7.43	1.92	4.44	7.67

Table 1 Cohort below 50 years of age. Shaft width (ST), intramedullary thickness (IMT) and medial cortical thickness (MCT), Hallux valgus (HV)

	2nd MCT	2nd IMT	2nd ST	3rd MCT	3rd IMT	3rd ST	4th MCT	4th IMT	4th ST
NORMAL (6M,23F)	2.76	3.86	8.21	2.40	3.41	6.77	1.93	3.84	7.11
HV (5M,18F)	2.57	4.27	8.63	2.20	4.00	7.29	1.75	4.35	7.31
HV AND PES PLANUS (3M,12F)	2.56	4.76	8.89	2.14	4.40	7.48	1.89	4.35	7.56
PES PLANUS (4M,1F)	2.57	4.51	8.76	2.17	4.20	7.38	1.82	4.35	7.43

Table 2 Cohort above 50 years of age. Shaft width (ST), intramedullary thickness (IMT) and medial cortical thickness (MCT), Hallux valgus (HV)

Maceria, et al., reported an 11-20% incidence of MTG in patients following Mitchell osteotomy [7]. They postulated this was due to the impairment of first ray function resulting in a compensatory increased load on the lesser metatarsals. The maximum force on the third and fourth metatarsals is in the midshaft, 3-4 cm distal to the base of the metatarsals and hence we measured at this site [8]. The maximum stress across a bone is dependent on the cross-sectional area of the bone as well the magnitude and direction of the load. Increased load results in cortical thickening and decrease in loading manifests as osteopenia, which is seen as cortical tunneling and appears radiologically as increased IMT [9].

In our study, there was a statistically significant increase in IMT of the third metatarsal in all patients with HV and HV with PP, which is due to altered biomechanics and relative decrease in load on the third metatarsal. The increased IMT was more pronounced in group 2 (patients over the age of 50 years) and 83.3% of patients in the group were women. Post-menopausal women are more prone to stress changes as the lack of estrogen can lead to osteoporosis. This is likely to reflect the increased IMT in group 2 (patients over 50 years) as this group was predominantly female. The relative increase in IMT and decrease in MCT of 4th metatarsal is likely to be relative osteopenia due to altered biomechanics resulting in relative decrease in loading through this. The study has a few limitations. This is a retrospective study. Patient's BMI/ body weight was not measured.

Conclusion

There is significant increase in the IMT of the third metatarsal in patients with HV and PP due to altered biomechanics. This needs to be considered as a source of pain in patients with MTG.

Disclosures: None

Acknowledgements: None

Declaration of Conflicting Interests: None

References

1. Reynolds JC. Developmental disorders: adult foot Part 2. Metatarsalgia. In: Gould JS, ed. The foot book. Baltimore: Williams & Wilkins; 1988. p. 219-227.
2. Stokes IAF, Hutton WC, Stott JRR. Forces acting on the metatarsals during normal walking. J Anat. 1979 Sep;129(3):579-590.
3. Al-Munajjed AA, Bischoff JE, Dharia MA, Telfer S, Woodburn J, Carbes S. Metatarsal Loading During Gait—A Musculoskeletal Analysis. ASME. J Biomech Eng. 2016 Mar;138(3):034503-034503-6. doi: 10.1115/1.4032413.
4. Hutton WC, Dhanendron M. The mechanics of normal and hallux valgus feet-A quantitative study. Clin Orthop. 1981 Jul-Aug;(157):7-13.
5. Simkin A, Leichter I, Giladi M, et al. Combined effect of foot arch structure and an orthotic device on stress fractures. Foot Ankle. 1989 Oct;10(2):25-9.
6. Doxey G. Management of metatarsalgia with foot orthotics. J Orthop Sports Phys Ther. 1985;6(6):324-33.
7. Maceira E, Monteagudo M. Transfer metatarsalgia post hallux valgus surgery. Foot Ankle Clin. 2014 Jun;19(2):285-307.
8. Arangio GA, Beam H, Kowalczyk G, Salath EP. Analysis of stress in the metatarsals. Foot Ankle Surg. 1998;4(2):123-128.
9. Bala Y, Zebaze R, Ghasem-Zadeh A, et al. Cortical porosity identifies women with osteopenia at increased risk for forearm fractures. J Bone Miner Res. 2014 Jun;29(6):1356-62.