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Case Report

Conservative treatment of Freiberg's infraction using foot orthoses: A tale of two prescriptions presented as a case study to open debate

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ABSTRACT

'Freiberg's infraction or disease' is an osteonecrotic process primarily affecting the 2nd & 3rd metatarsal heads. Early diagnosis is difficult, and the underlying pathogenesis remains unclear. Surgical options for late disease have been widely reported in the literature, yet details on conservative management for the early stages of Freiberg's are largely absent. Pathology should be treated where possible using an evidence-based approach, yet evidence for conservative management in acute stages of Freiberg's is lacking. A case study is presented that outlines two different prescription interventions using foot orthoses; one that attempted to 'offload' the metatarsal head by creating space beneath it; and one that attempted to 'offloaded' by increasing controlled loading of the metatarsals proximal to the head. These resulted in very different outcomes for the patient. The authors will attempt to give a 'pathomechanical rationale' for the treatment outcomes based on mechanical stress principles, and a consequential explanation as to why one type of insole prescription seemed more successful in reducing symptoms and raising activity levels, while another was not.

1. Introduction

Freiberg was the first to report the condition, describing six cases of 2nd metatarsal pathology in 1914 as an infraction, although the following year Kohler described the condition as an osteonecrosis of the second metatarsal head [[6–8]]. Freiberg's is reported as the fourth most common osteochondrosis [[6–8]], with 68% of cases occurring at the second metatarsal head [3] in a peak age range of 11–17year olds, during skeletal growth [4] at a ratio of 5:1 in females compared to males [5]. The dominant foot is involved in 36% of cases [[6–8]]. The aetiology remains poorly understood, although excessive tissue stress resulting in overload of the metatarsal head, creating micro trauma and cartilage degeneration, is the most widely accepted pathomechanical cause suggested [6–8].

Damage in adolescence from acute Freiberg's causes secondary osteoarthritis and metatarsalgia in later life, known as late stage Freiberg's [1]. It is the secondary problems associated with Freiberg's that in adulthood can lead to surgery and for which, treatment in the acute phase should be attempting to prevent. In the early stages conservative treatment to relieve weightbearing stress is recommended by decreasing/adjusting forefoot pressure by unloading affected metatarsals [7] such as by activity modification, orthoses and shoe adaptations [9,10]. However, details of conservative treatment is severely lacking in the literature. The textbook '*Introduction to Podopaediatrics 2nd edition' has only half a page on the disorder and advises, "Treatment is by means of rest and the provision of a metatarsal bar", and "..where there is a functional problem, orthoses may help*" [10]. The literature fails to specify where additions such as metatarsal bars should be placed, or which type of orthoses, materials or profiles should be used in Freiberg's management.

Surgery is an option for secondary symptoms developed in chronic stages of Freiberg's. Helal and Gibb [11] used Smillie's disease stages of Freiberg's to decide when surgery is indicated, also suggesting surgery is unsuitable in the acute phase. A variety of surgery options are widely proposed [11–18]. Whilst there are many papers looking at different surgical treatment of Freiberg's there is insufficient evidence to support one conservative treatment over another [[11–18]]. Conservative treatment is suggested as an attempt to preserve the joint space and maintain the range of motion in the metatarsophalangeal joint (MTPJ) during the acute phase and therefore avoid the need for surgery later.

2. Case presentation

A 14 year-old female adolescent presented to the clinic with a 7-

Abbreviations: MTPJ, metatarsophalangeal joint; US-CO, U-shaped cut outs; MP, metatarsal pad

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Photograph 1. The original right foot orthoses demonstrating a metatarsal bar and distinct U-shaped cut out to the 2nd metatarsal head.

month history of right forefoot pain and a diagnosis of active Freiberg's disease in her right 2nd metatarsal following treatment with high doses of steroids to treat an autoimmune liver complaint. Osteonecrosis is known to be common with high dose, steroid use [19].

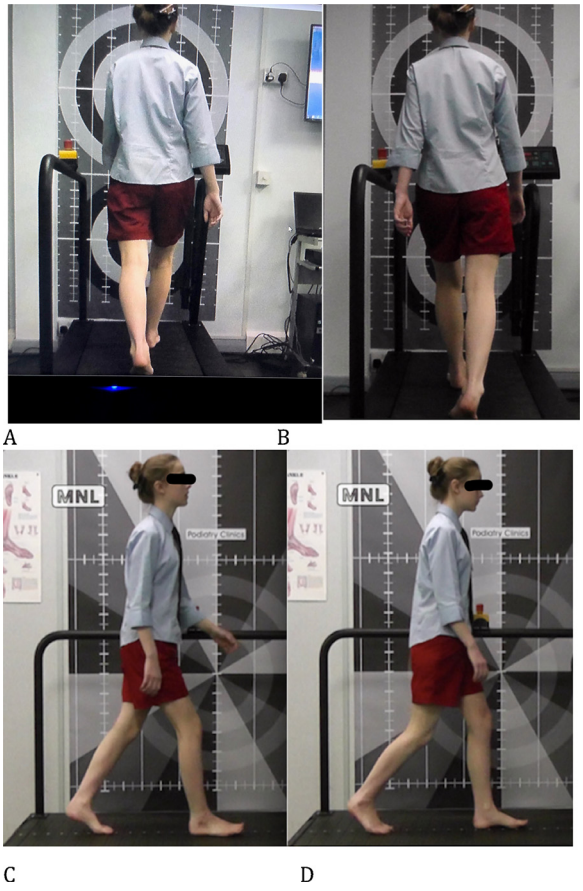
Freiberg's had been diagnosed previously via Orthopaedics and a right foot orthosis had been provided by the Hospital Orthotics Department to off-load the affected 2nd MTPJ, ten weeks prior to a second opinion being sort due to continued activity restriction and pain. The existing foot orthosis consisted of a flat insole with a combined metatarsal bar and medial arch-filling pad with a 'U'-shaped cut out (US-CO) to the 2nd MTPJ (Photograph 1). The patient felt the insole had helped reduce pain levels to a degree, but she was still symptomatic and unable to resume her dancing activities. She also reported that she had noticed that the right 2nd toe had started to 'claw'. On examination the right 2nd toe appeared retracted dorsally at the MTPJ, and flexed at the inter-phalangeal joints. The toe remained in this posture on standing, but was flexible and could reduced manually to the alignment of the other toes.

On gait analysis it was noted that the patient was using a high gear propulsion on the left foot (Photograph 2A), but a low gear propulsion as described by Bosjen-Møller [20], on the symptomatic right side (Photograph 2B). It was suspected that the terminal stance asymmetry of gait was a result of pain avoidance. Decreased knee flexion was also noted during terminal stance of gait on the right compared to the left (Photograph 2C&D). It was surmised that this was an attempt to reduce reaction forces across the forefoot after heel lift.

In-shoe pressure data analysis was undertaken using the F-Scan system (Tekscan™). Pressure data confirmed increased average (over multiple steps) lateral loading on the right foot compared to the left, probably resulting from an attempt to reduce loading on the painful 2nd MTPJ area (Fig. 1A). The centre of pressure line moved backwards on both feet during the final stages of terminal stance, suggesting poor anterior drive off the forefoot, but the centre of pressure on the left moved more medially during this period compared to the left which more stayed centrally aligned (Fig. 1A).

2.1. Change in intervention

Due the lack of significant symptom progress, the initial orthosis prescription of a US-CO combined with a metatarsal bar was changed for a preformed contoured foot orthosis with a metatarsal pad (MP) built in as standard (X-line®, Healthy Step™). The preform foot orthosis was then customised with the addition of a lateral forefoot post of 3 degrees using a low-density (shore 50) EVA wedge on the plantar surface of the right insole. This forefoot wedging started beneath and just proximal to the 2nd MTPJ and extended to the 5th MTPJ. This was to try and reduce the lateral shift in forefoot loading and establish some 2nd MTPJ loading during induced high gear propulsion (Photograph 3). On the dorsal surface of the insole, an extra 3 mm MP of a more compliant material (Astroshock™) was place just proximal to the 2nd and 3rd



Photograph 2. The patient in terminal stance phase of gait showed high gear propulsion (A), but low gear propulsion on the right symptomatic foot (B), possibly to avoid high loading the 2nd MTP. On the left the knee is near full extension during heel lift (C), while on the right the near is clearly more flexed at the equivalent stage of the gait cycle (D), possible reflecting an attempt to reduce forefoot reaction forces in the symptomatic forefoot.

metatarsal heads (Photograph 4). This addition was to reduce/delay peak forces under the 2nd metatarsal head during terminal stance as previously reported [21–24].

The left foot was provided with a balancing foot orthoses unadjusted from the manufacturers specifications. The foot orthoses were reported as comfortable and in-shoe analysis showed a more central progression of the centre of pressure and a consistent, lower forefoot pressure concentration at the MTPJs heads (Fig. 1B). The patient was also given exercises to improve the strength of her digital plantar flexors, involving picking up of an exercise ball [25], and other elements of short foot exercises, which have proven effective in provoking intrinsic flexor muscle strength in the foot [26].

Review at four weeks after fitting the new orthoses revealed a significant improvement in the patients reported comfort level (60% better). The patient had been able to return to her dancing lessons. At further follow up ten weeks after fitting, the patient reported a total resolution of symptoms and the right 2nd toe was no longer retracted and clawed when standing barefoot, but instead became fully loaded on the support surface.

3. Discussion: model of mechanical aetiology & treatment of Freiberg's disease

No aetiology for Freiberg's disease has been substantiated, and although conservative intervention is recommended in early stages of the disease, no conservative intervention is evidenced in the literature. This makes choosing the appropriate conservative intervention challenging.

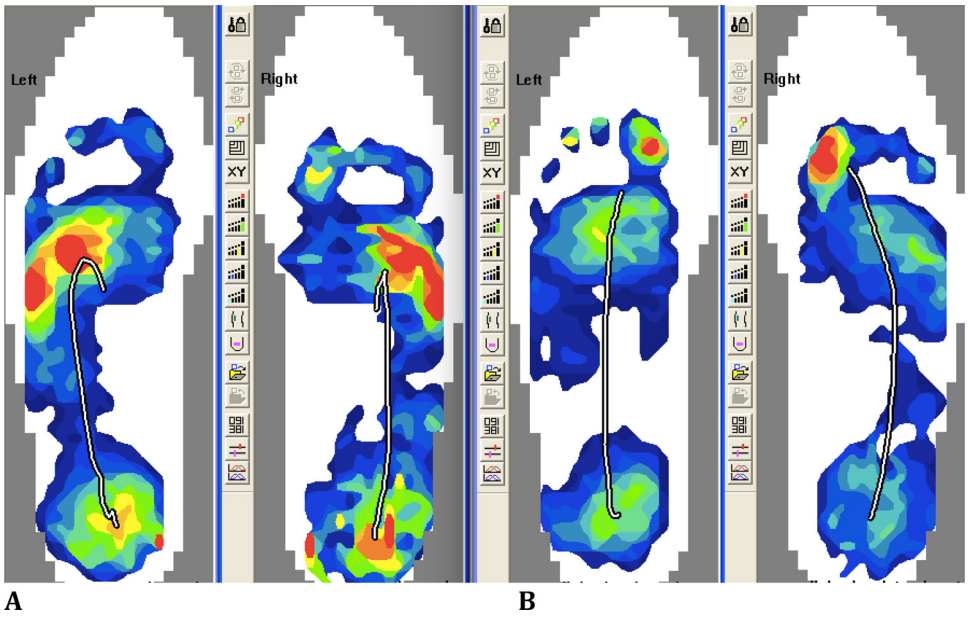
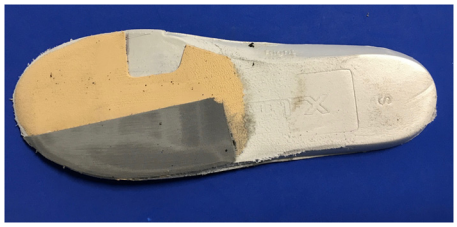


Fig. 1. Pressure data A shows the average pressure data over multiple steps and demonstrates a tendency to lateral forefoot loading, more noticeable of the left. The centre of pressure lines move posteriorly at the end of terminal stance suggesting poor anterior drive through the foot. Pressure data B records the average pressures of multiple steps with the customised preformed contoured foot orthoses in shoe with pressure sole placed over the orthosis.



Photograph 3. The customised underside of the right preformed foot orthosis.

Photograph 4. The positioning of the custom metatarsal pad on the dorsal surface of the preform foot orthosis in the frontal (top) and sagittal planes (bottom).

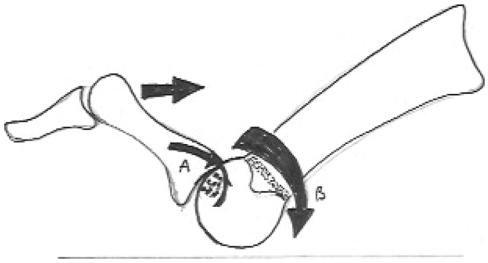


Fig. 2. Modified from an original drawing by McMasters MJ (1978). The pathogenesis of hallux rigidus. *Journal of Bone & Joint Surgery*. 60B:82–7. The original diagram shows a proposed mecbending moments at the metatarsal neck.

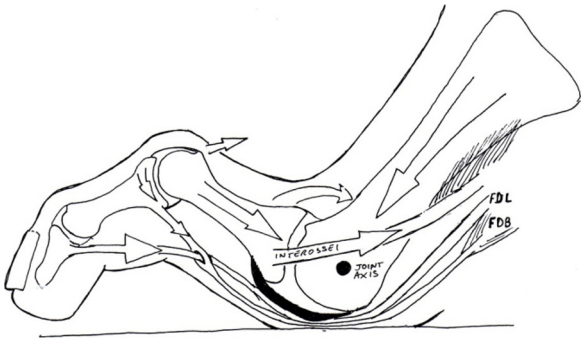


Fig. 4. An increase in metatarsal declination angle may change the function of the interossei tendons by increasing their position above the axis of rotation. Until the MTPJ undergo extension after heel lift the interrossei normally lie below the function axis, acting as plantarflexors. With increasing MTPJ extension and the loss of interrossei flexor stabilisation, the flexor digitorum longus and flexor digitorum brevis tendons lose their mechanical efficiency to maintain toe ground contact, leading to IPJ flexion, which compounds MTPJ extension motion and risks toe retraction and clawing.

The most widely accepted cause of Freiberg's is an excessive tissue stress resulting in micro trauma from overloading of the 2nd metatarsal head results in cartilage degeneration [6–8], yet the specifics of the mechanism remains unknown. One suggested possible mechanical cause describes excessive dorsiflexion of the proximal phalanx [27]. Although this mechanism is primarily used in explaining the pathomechanical process in the development of osteoarthritic changes in the 1st MTPJ, a suggestion is made that this process could be involved in Freiberg's [27], when the metaphysis is still active. This may induce extension moments through the growth plate of the immature metatarsal neck (Fig. 2).

Although US-CO, alternatively referred to as 'dells' are commonly used in foot orthosis prescription to offload a metatarsal head no published evidence was found during PubMed literature searches. It is possible that the prescription US-CO or dell will reducing pressure under the head initially, but may allow the metatarsal head to descend relative to its neighbours over time, increasing the functional metatarsal declination angle and thereby positioning the metatarsal head more inferiorly (Fig. 3). We propose that this will lower the position of

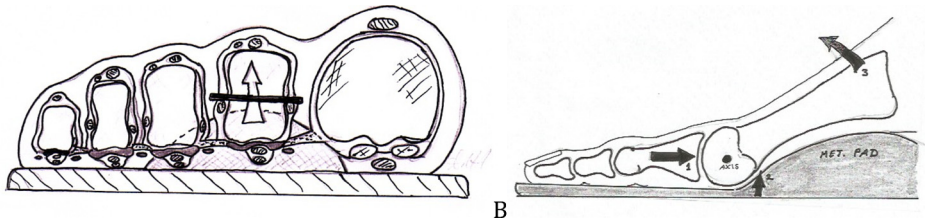


Fig. 5. The metatarsal dome placed behind the metatarsal head potentially elevates the metatarsal head and distal shaft, positioning the axis of the MTPJ above the interossei tendons allowing them to function as flexors for longer during gait (3A). This leads to a reduced metatarsal declination angle (3B), allowing the long and short digital flexors to work with the interossei to create a proximal flexion stabilisation force into the MTPJ (arrow 1). Ground reaction forces from the metatarsal pad (arrow 2) restrict metatarsal declination during metatarsal rotation during terminal stance and reduce ground reaction forces under the MTPJ (arrow 3).

the functional joint axis of the MTPJ, causing a change in the function of the interossei so that their tendons lie for an extended period in gait above the joint axis, becoming functional extensors for longer during gait (Fig. 4).

Pathological involvement of a change in the function of toe flexors is suggested by the report of acute Freiberg's in diabetic adults where neuropathy had resulted in small muscle atrophy [28]. This increased digit proximal phalanx extension is known to increase plantar pressure in diabetics [29] and may cause similar increased pressure in other wise mechanically 'tissue-healthy' populations. It was for this reason and the presence of the toe deformity that flexor exercises to the toes were initiated in this case.

The use of domed metatarsal pads has been shown to reduce mean peak plantar pressure over central metatarsals [21–24], with the optimum pressure reduction occurring with the metatarsal pad being place just proximal to the metatarsal head [22–24]. Despite these findings research into the use of metatarsal pads remains limited in symptomatic patients and their use in Freiberg's disease has not been investigated. The use of the MPs may reduce the range of digital extension and/or duration of digital extension by raising the metatarsal head and its axis of rotation of the MTPJ. In so doing the intrinsic muscle action, including the interossei, will be flexion dominant for longer. This in turn could mean the extension bending moment on the metatarsal neck/epiphysis was reduced (Fig. 5). This effect was potentially enhanced by the use of digital flexion strengthening exercises.

4. Conclusion

There is very little published literature on the conservative treatment of Freiberg's. A US-CO under a metatarsal head may reduce the plantar load to the metatarsal head but could theoretically increase metatarsal declination angle, thus increasing extension compression load on the dorsal aspect of the articular surface of the metatarsal through altering soft tissue alignment of the toe in relation to the position of the functional instantaneous joint axis location of the MTPJ.

In this case study, progress was limited whilst off-loading the joint with a US-CO and the digit in question was beginning to retract and claw, increasing passive extension position of the proximal phalanx. An adjusted-prefabricated foot orthosis prescription was tried to introduce some stable loading to the 2nd MTPJ and reduce forefoot pressures at the 2nd MTPJ, whilst keeping the proximal phalanx in a less extended position. This orthosis prescription approach was combined with active therapy by improving digital flexor muscle function with exercises. This combined stable-loading and digital flexor strengthening brought about a resolution of pain and deformity in this case.

A video of the exercises used in this case can be viewed at: https://www.youtube.com/watch?v=jb3vunKqYXo

Conflict of interest

LS and RL declare they have no competing interests.

AH works on a consultative basis and has financial links to Healthy Step Ltd. AH designed the X-Line preformed foot orthoses used in the management of this case.

References

[1] Carmont MR, Rees RJ, Blundell CM. Current concepts review: Freiberg's disease. Foot Ankle Int 2009;30:167–76http://doi.org/10.3113/FAI-2009-0167.
[2] Omer GE. Primary articular osteochondroses. Clin Orthop 1981;158:33–40.
[3] Gauthier G, Elbaz R. Freiberg's infraction: a subchondrial bone fatigue fracture. A new surgical treatment. Clin Orthop Rel Res 1979;142:93–5.
[4] Cerrato RA. Freiberg's disease. Foot Ankle Clin 2011;16:647–58http://www.doi.org/10,1016/j.fci.2011.08.008.
[5] Katcherian DA. Treatment of Freiberg's disease. Ortho Clin North Am 1994;25:69–81.
[6] Stanley D, Betts RP, Rowley DI, Smith TW. Assessment of etiological factors in the development of Freiberg's disease. J Foot Surg 1990;29:444–7.
[7] Talusan PG, Diaz-Collado PJ, Reach Jr JS. Freiberg's infraction: diagnosis and treatment. Foot Ankle Spec 2014;7:52–6. https://doi.org/10.1177/1938640013510314.
[8] Biz C, Zornetta A, Fantoni I, Crimi A, Bordignon E, Ruggieri P. Freiberg's infraction: a modified closing wedge osteotomy for an undiagnosed case. Int J Surg Case Rep 2017;38:8–12. https://doi.org/10.1016/j.ijscr.2017.07.013.
[9] Polin RA, Ditmar MF. Pediatric orthopaedic secrets. 3rd ed. Philadelphia: Mosby-Elsevier; 2010. p. 282.
[10] MacNicol M, Thompson P. Chapter 10: orthopedic conditions affecting the foot in childhood. Introduction to podopaediatics. 2nd ed. Edinburgh, Churchill Livingstone: Thomson P, Volpe R; 2001. p. 213.
[11] Helal B, Gibb P. Freiberg's disease: a suggested pattern of management. Foot Ankle Int 1987;8:94–102. https://doi.org/10.1177/107110078700800205.
[12] Kim J, Choi JC, Park YJ, Lee JW. Modified Weil osteotomy for the treatment of Freiberg's disease. Clin Orthop Surg 2012;4:300–6. https://doi.org/10.4055/cios.2012.4.4.300.
[13] Biz C, Zornetta A, Fantoni I, Crimi A, Bordignon E, Ruggieri P. Freiberg's infraction: a modified closing wedge osteotomy for an undiagnosed case. Int J Surg Case Rep 2017;38:8–12. https://doi.org/10.1016/j.ijscr.2017.07.013.
[14] Chao K-H, Lee C-H, Lin L-C. Surgery for symptomatic Freiberg's disease: extra articular dorsal closing-wedge osteotomy in 13 patients followed for 2–4 years. Acta Orthop Scand 1999;70:483–6. https://doi.org/10.31091/17453679900900985.
[15] Kinnard P, Lirette R. Freiberg's disease and dorsiflexion osteotomy. J Bone Joint Surg Br 1991;73B:864–5. https://doi.org/10.1320/0301-620x.73b5.1894683.
[16] Dolce M, Osher L, McEneaney P, Prins D. The use of surgical core decompression as treatment for avascular necrosis of the second and third metatarsal heads. Foot 2007;17:162–6. https://doi.org/10.1016/j.foot.2007.04.001.
[17] Smith TW, Stanley D, Rowley DI. Treatment of Freiberg's disease. A new operative technique. J Bone Joint Surg Br 1991;73-B:129–30. https://doi.org/10.1302/0301-620X.73B1.1991746.
[18] Helix-Giordanino M, Randier E, Frey S, Piclet B. Treatment of Freiberg's disease by Gauthier's dorsal cuneiform osteotomy: retrospective study of 30 cases. Orthop Traumatol: Surg Res 2015;101:s221–5. https://doi.org/10.1016/j.otsr.2015.07.010.
[19] Longworth R, Chockalingam N. Avascular necrosis: is there a role for biomechanical examination as a potential modality for its detection and treatment? Int Musculoskelet Med 2016;38:59–62https://doi.org/10.1080/17536146.2016.1243290.
[20] Bosjen-Møller F. Calcaneocuboid joint and stability of the longitudinal arch of the foot at high and low gear push off. J Anat 1979;129(Pt 1):165–76. PMC1233091.
[21] Jackson L, Binning J, Potter J. Plantar pressures in rheumatoid arthritis using prefabricated metatarsal padding. J Am Podiatr Med Assoc 2004;94(5):239–45.
[22] His WL, Kang JH, Lee XX. Optimum position of metatarsal pad in metatarsalgia for pressure relief. Am J Physic Med Rehab 2005;84(7):514–20. https://doi.org/10.1097/01.phm.000167680.70092.29.
[23] Brodtkorb T-H, Kogler GF, Arndt A. The influence of metatarsal support height and longitudinal axis position on plantar foot loading. Clin Biomech 2008;23:640–7. https://doi.org/10.1016/j.clinbiomech.2007.09.019.
[24] Chen W-M, Lee S-J, Lee PV. Plantar pressure relief under the metatarsal heads-therapeutic insole design using three-dimensional finite element model of the foot. J Biomech 2014;48:659–65. https://doi.org/10.1016/j.biomech.2014.12.043.
[25] Branthwaite N, Grabtree G, Chockalingham N, Greenhalgh A. The effect of toe flexion exercises on grip. J Am Podiatr Med Assoc 2018;108:355–61.
[26] Jung D-Y, Kim M-H, Koh E-K, Kwon O-Y, Cynn H-S, Lee W-H. A comparison in the muscle activity of the abductor hallucis and the medial longitudinal arch angle during toe curls and short foot exercises. Phys Ther Sport 2011;12:30–5. https://doi.org/10.1016/j.ptsp2010.08.001.
[27] McMasters MJ. The pathogenesis of hallux rigidus. J Bone Joint Surg 1978;60B:82–7. https://doi.org/10.1302/0301-620X.60B1.627584.
[28] Nguyen VD, Keh RA, Daehler RW. Freiberg's disease in diabetes mellitus. Skeletal Radiol 1991;20:425–8. https://doi.org/10.1007/BF00191084.
[29] Mueller MJ, Hastings M, Commean PK, Smith KE, Pilgram TK, Robertson D, et al. Forefoot structural predictors of plantar pressure during walking in people with diabetes and peripheral neuropathy. J Biomech 2003;36:1009–17. https://doi.org/10.1016/S0021-9290(03)00078-2.