Comparison of Plantar Pressure Distribution between Hallux Valgus and Normal Feet Using Foot Pressure Platform

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Background

Hallux Valgus (HV) was first described by Carl Heuter in 1871 as a deformity affecting the first metatarsal joint of the foot [1] (Figure 1) and involves medial displacement of the 1st metatarsal with lateral displacement of the great toe [2]. Approximately 97% of HV patients present with bilateral deformity [3]. It is a common condition affecting 28.4% of adults [4] and 74% of the elderly population in the UK [5]. It is more common in females than males with a ratio of 5:1 [6].

Due to involvement of the 1st ray in HV, the pattern of the plantar pressure distribution will differ from normal feet. Modern foot pressure measurement technology, such as foot pressure platform, allows biomechanical analysis of the pressure during dynamic and static stats. This provides valuable information for clinicians about the pathological changes in the foot mechanics and function. The main aim of this study is to compare the plantar pressure in HV feet with healthy feet during walking.

Figure 1. Bilateral Hallux Valgus deformity

Methods

Six participants (12 feet) with mild to severe HV (mean HV angle 36.95°, Inter-metatarsal angle 12.84° and sesamoid displacement of 70%) were compared to 20 healthy participants (40 feet). Approval was obtained from NHS research ethical committee.

Emed-x400 platform was used which allowed dynamic and static measurements of foot pressure. The platform was placed in the middle of 10m walk way to allow mid-gait analysis. A mask system was used to divide the foot into 10 regions: heel, midfoot, first, second, third fourth and fifth metatarsal heads, great toe, second toe and 3rd to 5th toes (Figure 2). Only six parameters having the most clinical relevance where selected for analysis: peak pressure (PP), Contact Area (CA), Contact Time (CT), Maximum Force (MF), Force-time-integral (FTI) and Pressure–time integral (PTI).

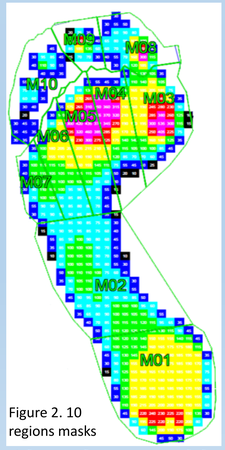

Figure 2. 10 regions masks

Subjects were allowed to familiarise themselves with study protocol by walking over the platform multiple times and a starting point for the first step was marked. Four trials for each foot were recorded.

Result

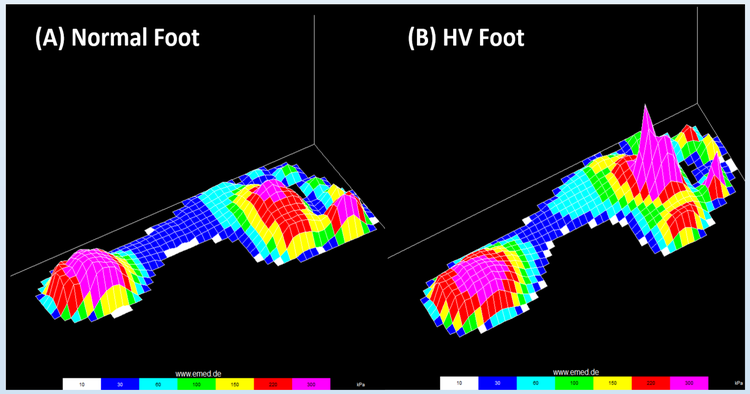

Figure 3. 3D peak of pressure **(A)** Normal vs **(B)** Hallux Valgus foot

Figure 4. Peak Pressure distribution between Normal and HV feet

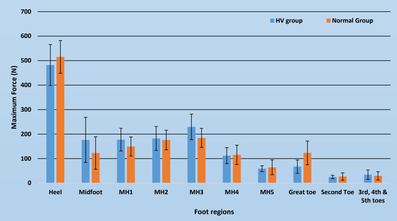

Figure 5. Maximum Force between HV and Normal groups

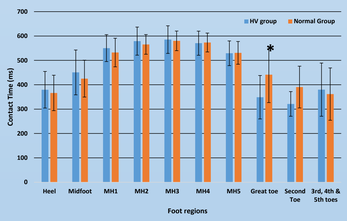

Figure 6. Contact Time of the foot in HV and Normal groups

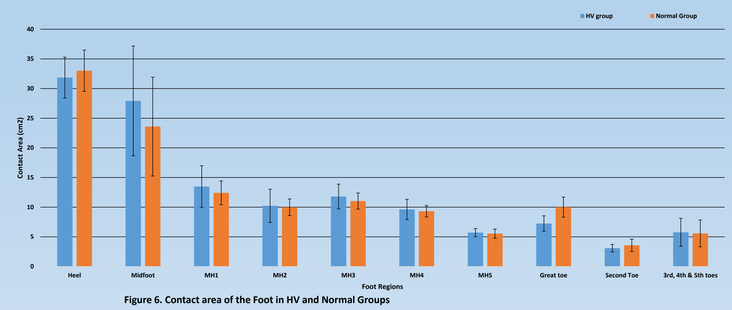

Figure 6. Contact area of the Foot in HV and Normal Groups

Figure 7. Contact area of the foot in HV and Normal groups

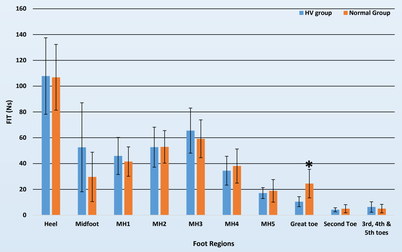

Figure 8. Force Time Integral in HV and Normal groups

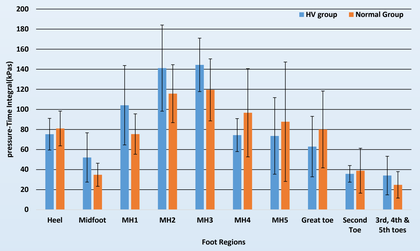

Figure 9. Pressure Time Integral in HV and Normal groups

Discussion

Peak of Pressure:

The highest PP in HV group was found under the second metatarsal head followed by the third metatarsal head, the first metatarsal, great toe and heel. However, only PP under the third metatarsal head was highly significant ($p<0.05$). In the healthy feet the highest PP was found under the second metatarsal head followed by heel, third metatarsal head and great toe. This finding is associated with hallux valgus feet compensating the mechanical dysfunction in the 1st MTP joint by shifting the pressure toward the lateral side of the foot especially during push off. However, there was a drop in peak of pressure from 3rd to 4th and 5th metatarsal heads. This is associated with alteration of loading pressure distribution pattern of the 1st ray (Figure 4).

Contact Time and Area:

Both HV and normal groups showed the heel with the largest CA (mean 31.85 and 33cm^2 respectively). However, the great toe in HV showed significantly lower contact area with mean 7.24cm^2 comparing to the healthy group with 10.01cm^2. In terms of CT, the HV group showed shorter contact time under the great toe with 348ms comparing to healthy group of 441ms. The reduction of the great toe contact area and time are associated with abduction of the hallux toward the latter. This results in less contact area and time of the great toe during walking.

Maximum force and Force Time-Integral:

The HV group demonstrated increased force underneath the 3rd metatarsal head and reduction under the great toe. This was associated with the foot compensating by loading force under the 3rd metatarsal head during push off. The reduction of the great toe's force was associated with abnormal abduction of the toe and inability to carry normal mechanic function during push off. These finding are supported by the significant reduction of the great toe in FTI (10.44Ns) in HV group compared to normal group (24.46Ns).

Conclusion

Early results demonstrate the HV group has significant high PP under the 3rd metatarsal head and low CA and FTI under the great toe. The 1st metatarsal joint is important in providing stability of the medial arch and distribution of load during dynamic walking. Due to the involvement of the 1st metatarsal phalangeal joint plantar pressure distribution differs in the HV group in comparison to the healthy group.

REFERENCES

[1] Ehrlich (1965); [2] Coughlin (1996); [3] Young et al., (2013); [4] Roddy et al., (2008); [5] Menz et al., (2010); [6] Nix et al., (2010)