

ANALYSIS OF FORCE DISTRIBUTION PATTERN UNDER THE FORE-FOOT IN PATIENTS WITH HALLUX VALGUS DEFORMITY

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Abstract

The purpose of this paper is to study the force pattern distribution under the fore-foot areas with and without Hallux Valgus deformity. Hallux Valgus (HV) is one of the most common foot deformities. Plantar force pattern in HV patients has been widely studied in previous published papers to identify HV condition according to their plantar force pattern. This condition occurs by the ratio of two to one women to men. People with HV have altered pressure pattern. As 23% of people develop such condition, studying and understanding the plantar force pattern is essential. Furthermore, speed of walking has an effect on force changes under the foot. So in order to examine the effect of different walking speeds on plantar force pattern, twenty people ten with and ten without HV took part in the test by walking on the pressure mat. The results showed that the variability in force pattern in the same individual was significant from one trial to another which can be concluded that obtaining consistent force pattern is an issue to overcome. After getting consistent force readings, it was observed that the higher load was under the 2nd and 3rd metatarsal heads in people with HV which was significantly different from non-HV participants. There are contradictory opinions in previous published papers on plantar pressure pattern as a means of identifying HV. Furthermore, analysing force pattern is a hurdle to overcome. As walking speed has significant effect on plantar pressure patterns, the study of this issue is badly needed.

Keywords: Hallux Valgus, force pattern, walking speed

Introduction

The most common known bone deformity is HV in which 35.7% of elderly develop it during their lives and 23% of adults affected by this condition (Nix, Vicenzino, Collins, & Smith, 2012). The prevalence of HV is 2 to 1 women to men because women wear more fashionable shoes which

restricts the toe movements inside the shoe and following that, the mechanical changes occur especially in fore-foot region (Nguyen et al., 2010). HV deformity is shown in figure1.



Figure1: Foot with Hallux Valgus deformity (LFAC, 2014)

This deformity is associated with the risk of falling and abnormal pressure distribution (Drake, R.J, Vogl, W, Mitchell, A.W.M, 2005). The study done by Rao et al., shows that people with flat feet has tendency to get some deformities such as Hallux Valgus, hammer toes, diabetes mellitus and peripheral neuropathy as they have higher load under the hallux compared to people with high arch and normal arch feet (Rao et al., 2011).

The 1st metatarsal joint and the hallux play an essential role in transferring the body's weight during locomotion (Mickle, Munro, Lord, Menz, & Steele, 2011). In another study, scholars claimed that maximum force is higher in the medial part of the metatarsals in the fore-foot region (Nyska, Liberson, McCabe, Linge, & Klenerman, 1998). Plank (1995), examined volunteers with and without HV and found that in the non-HV group members the highest pressure was on 3rd, 2nd, 4th and 1st metatarsal heads and 5th metatarsal head was received the lowest pressure. Furthermore, in the HV group the maximum pressure was on the 3rd, 2nd, 1st, 4th and 5th metatarsals (Plank, 1995).

Maximum force and peak pressure increased in all foot regions at fast walking speeds, excluding the lateral midfoot, first metatarsal and third–fifth metatarsal regions (Taylor, Menz, & Keenan, 2004). In contrast, in the study done by Rosenbaum et al., he claimed that the pressure under the medial part of the fore-foot increased with increasing the walking speed, in this study the significant changes were found in 1st, 2nd and 3rd metatarsal regions. (Rosenbaum, Hautmann, Gold, & Claes, 1994). In this study the differences in force distribution patterns under the right foot of volunteers

with and without HV was examined. Furthermore, the comparison of the force distribution under the foot was done to examine the speed variable on plantar loading in fore-foot area.

Methods

Subjects

Twenty volunteers took part in the experiment. Ten with HV deformity and ten without HV. *Foot-scan advanced & hi-end system* (RSscan International NV, Belgium) was used to record force distribution over the 10 anatomical zones under the feet including toe1, toe2-5, metatarsals 1-5, heel medial and heel lateral to evaluate the plantar force differences in two different speeds and in fore-foot areas, especially in the metatarsophalangeal joints.

Informed consent was obtained before the test from each participant (12 females and 8 males). Mean age of participants was 39.25 years old, and the mean weight was 68.75 kg. The collected force was normalized to the body weight of each volunteer and the time was normalized to 100 frames.

Experimental set up and data collection

A six meter long track was chosen and the RSscan device was located in the middle of the track. Before the actual test, the calibration process was done in order to get the accurate results in which the operator walked on the pressure mat to activate all sensors located inside the mat.

The test was done in two different speeds: slow and fast: 0.4 - 0.45 milliseconds for the slow speed and 0.32 – 0.35 milliseconds for the fast speed. The tests were conducted in two sessions, in each session participants walked on the mat three times for the familiarisation process before the actual test. Ten walking trials were obtained for each individual and for each speed.

Analysing force data

Plantar force distribution patterns collected from the tests and two methods were employed to analyse the data, first, comparing the average maximum force in fore-foot region, and the second one was an Independent sample T-test. These methods of analysis were done for all volunteers and on both speeds.

Comparing the average of maximum force

The average of maximum force that applied to each fore-foot region was calculated. The average of the all trials was obtained, so that for each volunteer, one average number could be used for making a comparison between the two groups to assess whether the average is higher in one group

than the other. This procedure also was done for the fast speed of each volunteer.

The maximum force that applied in every region in the fore-foot area in all trials was obtained, then the average of those calculated and the comparison in HV and non-HV groups was done to see whether the HV patients bear the higher force compared to non-HV participants. Then Independent Sample T-test was carried out to see whether the forces that applied on the fore-foot region of both groups of volunteers are significantly different. Slow speed results were compared with the fast speed results.

Independent sample T-test

This test is used when comparing the mean scores of two different groups regarding an identified condition. For conducting the test, two variables are needed, one which is categorical and serves as the independent variable (the HV and non-HV groups). The other is the continuous dependent variable, which, in this case, is force. The Independent Sample T-test outcome indicates whether there is a statistically significant difference in the mean profile between the groups (Pallant, 2005). This value (*P* value) is defined as 0.05, if the results of comparison between two groups of data obtain more than this value, groups are not significantly different and if the obtained value is less or equal to 0.05, the groups are significantly different. To investigate the force magnitude differences under the fore-foot region in both groups, this test was carried out using the software “IBM SPSS statistics DATA Editor”. The comparison was made for seven regions of the fore-foot: toe 1, toes 2-5, and metatarsals 1 to 5 for both speeds.

Results and Discussions

In this study the differences of plantar force pattern in HV and non-HV participants were analysed and compared.

In all, the volunteers' force graphs, the total frames recorded while walking were normalised to 100 frames and the force data in the Y axis normalised to that person's body weight. In Figure2, each graph shows dimensionless force in the Y axis against normalised frames in the X axis. Figures 2 and 3 present the force distribution under the ten anatomical regions of the foot. Figure 2 presents three samples of the force distribution graphs out of ten.

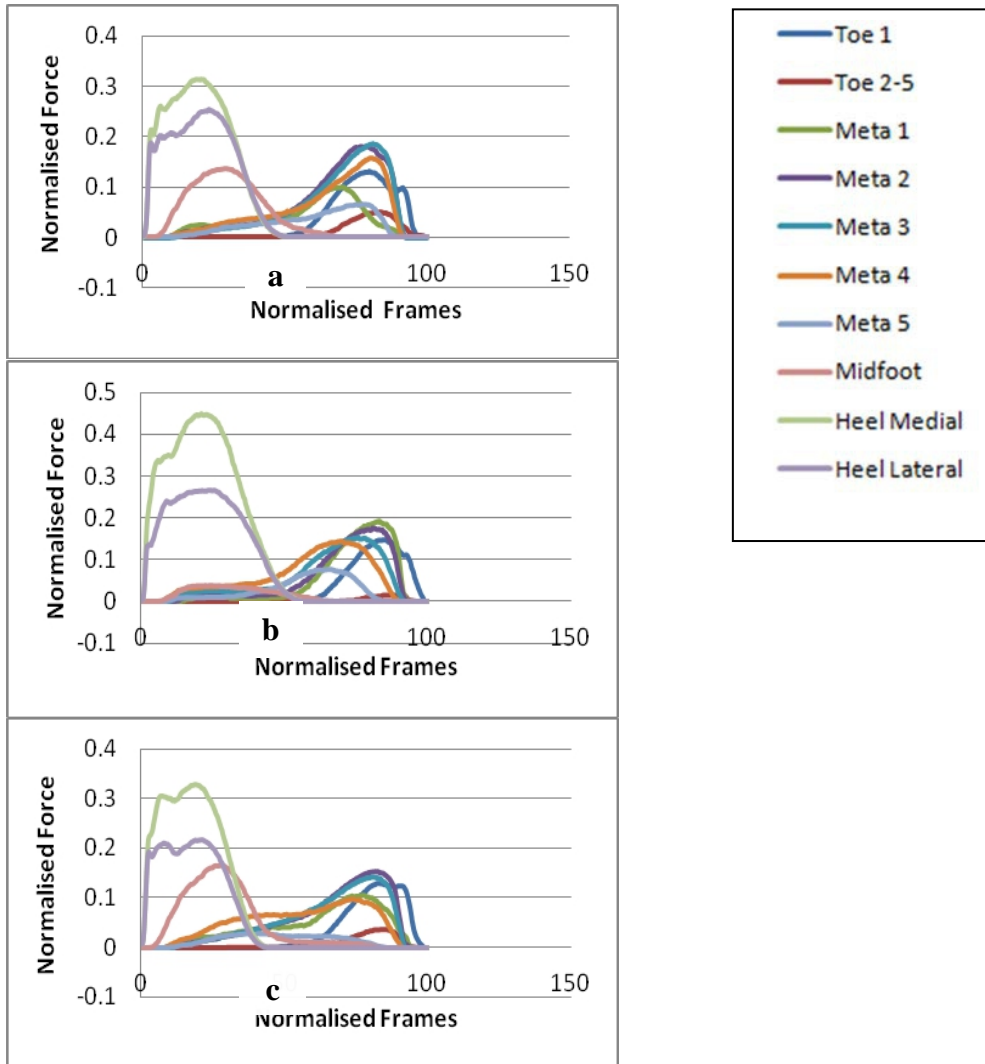


Figure2: Three sample trials showing the force in anatomical regions of the foot against normalised frames in a patient with HV. The highest force under the fore-foot is received by the 3rd, and 2nd metatarsal heads.

In Figure 2, HV patient shows to bear higher force under the 2nd and 3rd metatarsal heads and in non-HV participant the higher force was under the same regions following by 1st metatarsal head.

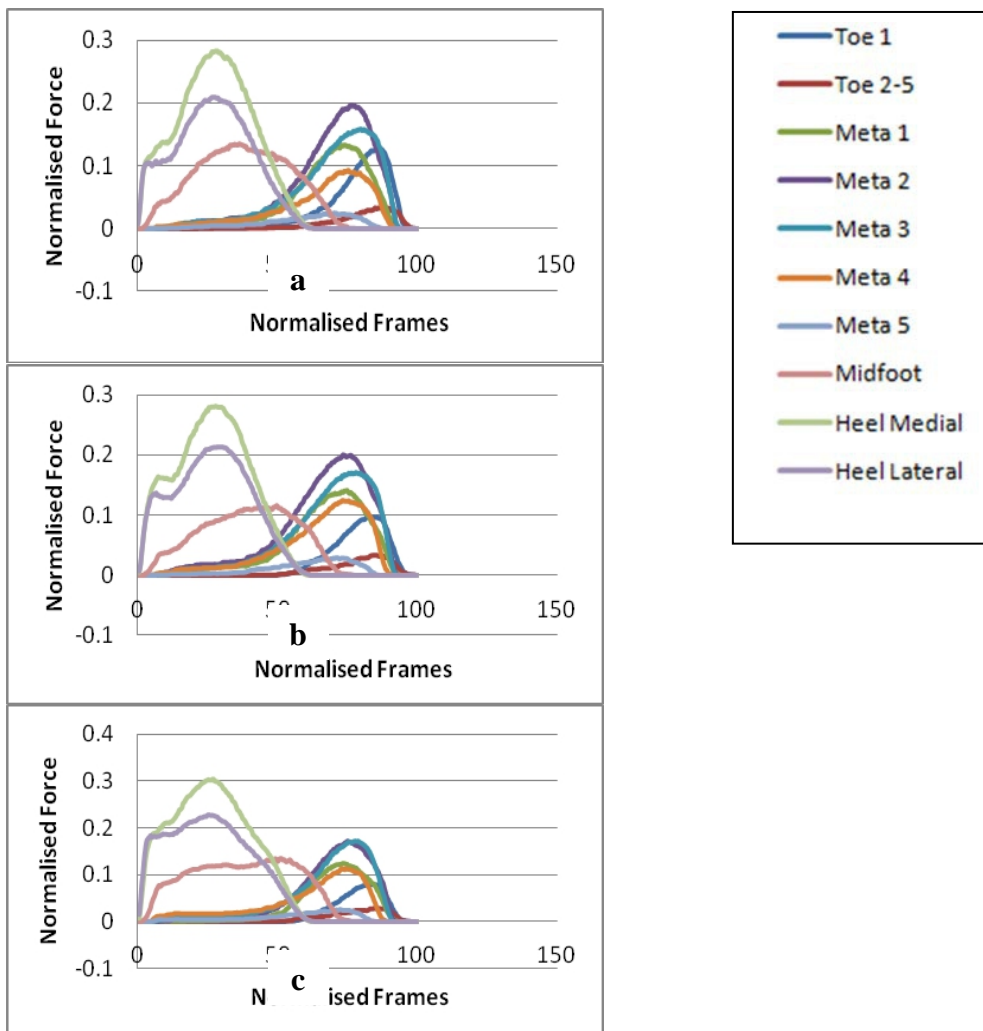


Figure 3: Three sample trials, force in ten anatomical regions of the foot against normalised frames in a non-HV volunteer shows that the highest force in fore-foot in under metatarsals 2nd, 3rd following by 1st metatarsal heads.

The average of the maximum force in fore-foot region was calculated and compared in both groups of volunteers. The results of comparison of maximum force show that people with HV beard higher force under the 1st, 2nd, and 3rd metatarsal heads compared to non-HV participants in slow speed.

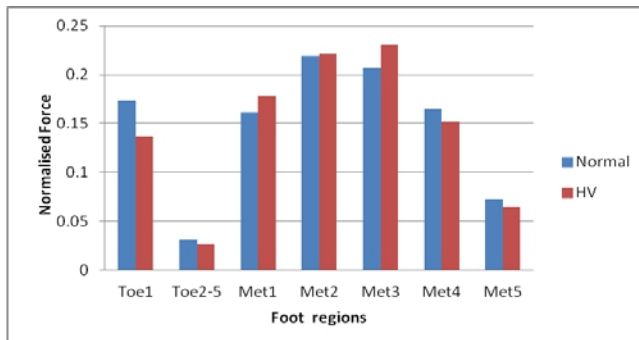


Figure 4: Comparison of average of maximum force distributed in fore-foot areas in HV and non-HV groups, metatarsals 1, 2 and 3 show to bear higher force compared to non-HV individuals in slower speed. Red represents HV volunteers and blue represents non-HV volunteers.

While participants stepped on the mat with slower speed the force transferred from heel region towards toes and as figures 2 and 3 shown, the higher force excluding the heel was received by metatarsal areas especially 2nd and the 3rd. Figure 4, shows that except metatarsals 1, 2 and 3 in other fore-foot regions, non-HV participants received the higher force including toe1, toe2-5, metatarsal 4 and 5. Table 1 shows the mean comparison of the forces received by fore-foot region and presents the significant differences between HV and non-HV group based on applied forces to the fore-foot regions.

In slower speed except for the toe2-5 and metatarsal 2, in all other regions, the applied force was significantly different in HV patients compared to non-HV participants as $p < 0.05$.

Table1: Comparison of the mean differences in HV and non-HV groups for slow speed obtained by Independent Sample T-test in which in all regions except toe2-5 and 2nd metatarsal significant differences were observed, as $p < 0.05$.

Fore-foot regions	P Value
Toe1	0.013
Toe2-5	0.197
Metatarsal 1	0.001
Metatarsal 2	0.142
Metatarsal 3	0.001
Metatarsal 4	0.001
Metatarsal 5	0.001

The comparison of the maximum force under the foot in both groups and in fast speed shows that except for the toe 2-5, in other fore-foot areas, the higher force was received by HV participants.

Figure 5, presents the comparison of the maximum force under the fore-foot of all participants in fast speed.

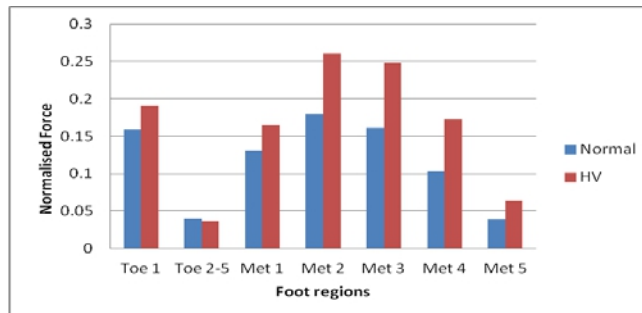


Figure 5: Average of maximum of normalised force distributed in fore-foot areas in HV and non-HV participants for the fast speed.

To see whether the applied force in fore-foot regions differs in HV participants compared to non-HVs, T-test was conducted on the same regions and in both speeds. The results related to fast speed is shown in Table 2.

Table 2: Comparison of the mean differences in HV and non-HV groups for the fast speed obtained by Independent Sample T-test in which in all regions excluding 2-5, the significant differences can be seen where the $p < 0.05$.

Fore-foot regions	P Value
Toe1	0.001
Toe2-5	0.640
Metatarsal 1	0.001
Metatarsal 2	0.001
Metatarsal 3	0.001
Metatarsal 4	0.001
Metatarsal 5	0.001

Conclusion

In this study the plantar force distribution under the foot was measured and compared to identify people with HV from their plantar force pattern. To obtain that, twenty participants ten with HV and ten without took part in the experiments.

The process of walking was done in two different speeds and consistent results were obtained from each volunteer and in each speed. The force data was compared in both groups. The comparison of the average of maximum force received by the fore-foot regions was conducted and it was observed that people with HV had more load on their 2nd and 3rd metatarsal heads compared to non-HV individuals. Furthermore, the results of the comparison of maximum force showed that when the speed increased the load applying to the metatarsal regions especially 3rd and 2nd ones significantly increased.

In the fast speed the load was significantly higher in all regions except for toe2-5 in HV participants which can be concluded that walking speed had an extensive effect on the load received by the fore-foot region.

Although many investigations have been done in previously published works on HV, many of them neglected the importance of speed. It is difficult to make a conclusive remark that this is a firm indication of the condition given that other variations reported in this report. Even if such results were taken to be conclusive indicators of the condition as claimed by many previously, it is worth stressing that our investigation showed no such pressure increase within the population considered to be vulnerable to the condition.

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