Plantar Pressure Distribution in Patients with Flexible Flat Foot, High Arched Foot and Diabetic Foot Without Neuropathy Versus Normal

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ABSTRACT

The purpose of this study was to determine the plantar pressure distribution in adult subjects suffering from flexible flat foot, high arched foot and diabetic foot without neuropathy versus normal using a pedobarograph. The plantar pressure of foot distribution regarding flexible flat foot, high arched foot and diabetic foot without neuropathy and normal subjects was measured during static and walking in each subject during normal walking speed. Sixty male subjects contributed in this study divided into four groups, the first group is flexible flat foot, the second group is high arched foot, the third group is diabetic foot without neuropathy, and the fourth group is the control or normal subjects. Time series pressure measurements for all sensors were grouped into five anatomical areas of human foot. In normal subjects, the hind foot (heel) was the first part of the foot receiving the weight bearing of the body. Then it moved to the toe through the midfoot and the metatarsal area. The highest mean pressure in normal subjects was found posterior in the hind foot under the heel and then anterior under the metatarsal heads. The lowest pressure distribution was under the cuboid bone. The highest mean plantar pressure distribution in the flat foot subjects was found under cuboid bone compared to normal subjects. The highest mean plantar pressure distribution in the high arched foot subjects or pes cavus was lower under all parts of foot. The highest mean of plantar pressure distribution in the diabetic foot without neuropathy was found under both forefoot and rear foot.

INTRODUCTION

Now the plantar pressure has been accepeted as a vital biomechanical parameter to evaluate walking of the human. The distribuation and magnitude of plantar pressure can provide useful information to diagnose varity of foot disorders[12].

The plantar pressure measurments during standing, walking and running can demonstrate the pathomechanics of foot disorders and give objective measures to track disease progression. Several studies in foot biomechanics have reported the plantar pressure variations is useful to determine pathological gait. Pathological gait can be divided on the basic etiology either neuromusclar or muscloskeletal[9].

The feet are considered as an important part of our body . It support not onley the whole body weight but also bears several times of body weight when we are running or splitting[15]. Many research groups used the potenital of pressure measurment technology for the diagnosis and treatment of different foot disorders[19].

Flexible flatfoot is one of the most common types of flatfoot. It typically begins in childhood or adolescence and continues into adulthood. It usually occurs in both feet and generally progresses in severity throughout the adult years. As the deformity worsens, the soft tissues (tendons and ligaments) of the arch may stretch or tear and can become inflamed The term "flexible" means that while the foot is flat when standing (weight-bearing), the arch returns when not standing[13].

Symptoms, which may occur in some persons with flexible flat foot, include:

- Pain in the heel, arch, ankle, or along the outside of the foot.
- Pain associated with shin splint.

General weakness or fatigue in the foot or leg[13].

Pes Cavus is defined as foot with an excessively high arch. It occurs in up to 15% of the population, of which 60% will develop foot pain .the Common complaints associated with pescavus include pain under the metatarsal heads and the heel, lateral ankle sprains, and footwear issues[2].

Lateral ankle instability and a laterally deviated subtalar joint axis (STJ) are frequently associated with high arched feet.

This lateral position of the STJ axis results in excessive supinatory torque around the subtalar joint axis. The prescribed orthosis should be designed to resist this excessive supination[4].

Diabetes is a complex group of syndromes that result in malfunction of the beta cell located in the islets of Langerhans of the Pancreas, whose function is the production of insulin. Complications of diabetes affect all body systems including the neuromuscular system in the form of sensory, motor and autonomic neuropathies[11].

People with diabetes by timing suffer from muscles weakness in the antigravity muscles and loss of balance and co-ordination[5].

The plantar pressure studies in patients with diabetic foot neuropathy have indicated a relationship between excessive localized pressure and foot ulceration. These patients are risk of recurrent ulceration and impaired pain because of increased pressure under the metatarsal heads. The effect of variation of foot pressure during gait in normal foot versus pes planus, pes cavus and diabetic foot without neuropathy is not fully understood so that the need of this study was necessary[6].

SUBJECTS AND METHODS

Patients population:

Sixty male subjects contributed in this study divided into four groups, the first group is flexible flat foot, the second group is high arched foot, the third group is diabetic foot without neuropathy, and the fourth group is the control or normal subjects matching in age, sex, weight, height and socio-economic level to the three study group. The four groups were selected on the basis that they have no past history of any musculoskeletal problems. The age of both study and control group was between 30 and 40 years.

Equipment and methods:

Plantar pressure distribution was performed with a pedobraograph (T&T medilogic Medizintechnik, GmbH Munich, Germany) based on shoe insoles with capacitive sensors with static and dynamic data collected for both feet. Pedobarograph provides information about the pressures on the plantar surface of the foot. It indicates the high pressure areas and also shows the progression of the center of pressure.

Dynamic data were collected with the patient walking at their natural self-selected speed. The data for each sensor were sampled with the frequency of 60 Hz and transferred to a computer via a wireless connection.

To assess plantar pressure spatial distribution, the time-series of the measured pressure amplitudes of all sensors were grouped into five anatomical masks[16] (figure 1). These masks corresponded to the following anatomical areas: the toes; the metatarsal heads; the navicular bone; the cuboid bone; and the heel.

During the experiment of the pressure distribution, the contact area of each mask, and the time of surface contact of each anatomical area were measured.

The pressure distribution value Pt depends on body mass, the surface contact of each anatomical area and the time of surface contact of each anatomical area as below:

$Pt \propto f(m, s, t)$[1],

where:

Pt – the value of plantar pressure

m – the body mass

s – the surface contact of each anatomical area

t – the time of surface contact of each anatomical area.

The pressure value should fit to the full range from zero to the absolute maximum determined by the body mass and the contact area of one sensor[10]. Maximum pressure was defined as the greatest pressure in each anatomical area of foot in a single step, and these values were averaged separately for each mask over 10 steps.

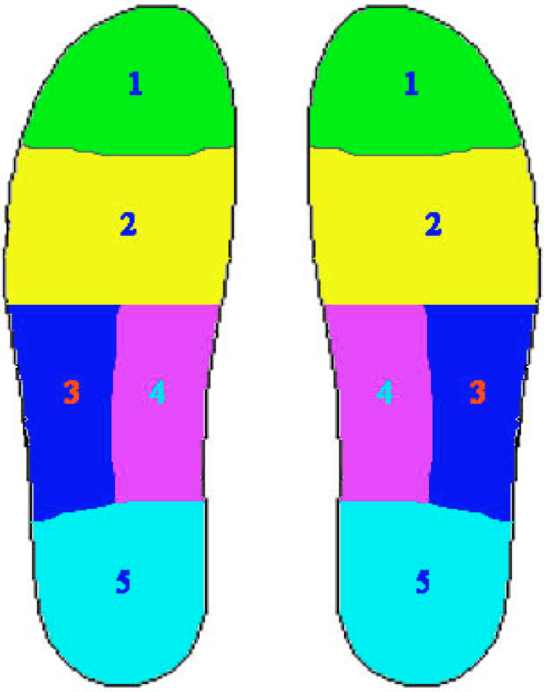

Fig. (1): Anatomical areas of human foot (Sviridenok, 2008).

Statistical Analysis

The differences in pressure distribution, the contact area of each mask, and the time of surface contact of each anatomical area were tested with t-test.

Means and standard deviations were calculated for the total subject sample for the data from the pedobarograph.

RESULTS

In normal subjects, the hind foot (heel) was the first part of the foot receiving the weight bearing of the body. Then it moved to the toe through the midfoot and the metatarsal area.

The highest mean pressure in normal subjects was found posterior in the hind foot under the heel and then anterior under the metatarsal heads. The lowest pressure distribution was under the cuboid bone.

The highest mean plantar pressure distribution in the flat foot subjects was found under cuboid bone compared to normal subjects.

The mean of plantar pressure distribution in the high arched foot subjects or pescavus was lower under all parts of foot.

The highest mean of plantar pressure distribution in the diabetic foot without neuropathy was found under both forefoot and rear foot.

Figure (2) presents the pressure distribution in the normal subjects. The foot pressure distribution is mainly shared by central part of heel, the metatarsal heads and big toe.

A significant part of the load is taken by forefoot, but the peak pressure is located in the central part of the heel. The pressure values under the metatarsal heads are more or less the same as that under central heel. The medial part of the foot takes a very small part of a load due to skeletal structure of the foot.

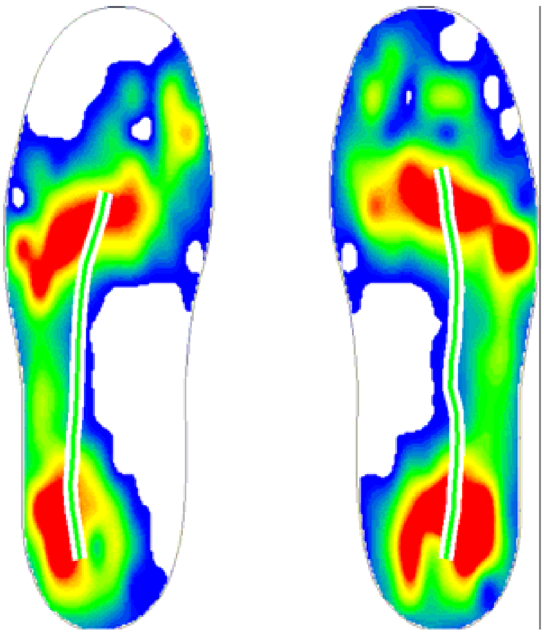

Fig. (2-A): Pressure distribution during walking.

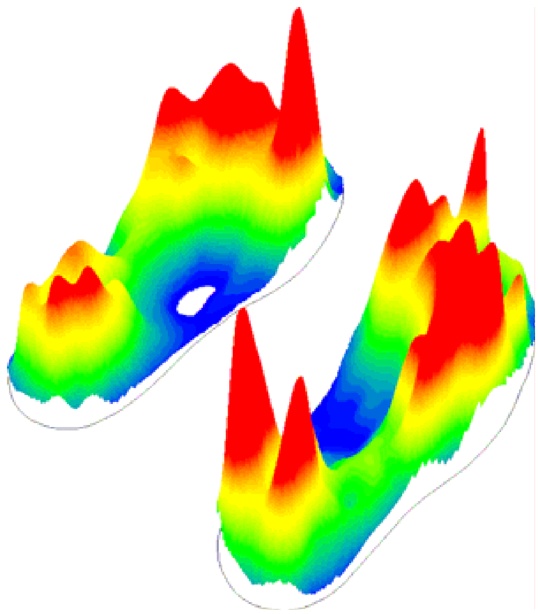

Fig. (2-B): Pressure distribution during standing (Burns et al., 2006).

Table (1): The pressure distribution for the pesplanus, pescavus,and diabetic foot without neuropathy versus control subjects during walking (±SD).

Foot area	Normal foot	Pescavus	Pesplanus	Diabetic foot without neuropathy
1	4.7 ± 2.7	2.9 ± 0.6	4.3 ± 2.5	4.5 ± 2.3
2	16.1 ± 2.5	14.8 ± 0.8	14.9 ± 2.8	16. ± 2.2
3	6.5 ± 1.5	2.7 ± 0.9	3.3 ± 1.2	6.2 ± 1.2
4	2.8 ± 0.5	1.6 ± 0.6	4.3 ± 1.7	2.6 ± 0.4
5	21.7 ± 2.4	16.9 ± 0.8	18.2 ± 1.9	21.5 ± 2.2

Table 1 summarized the pressure distribution for the pesplanus, pescavus,and diabetic foot without neuropathy versus control subjects during walking.

For control subjects, the highest pressure amplitudes were found under the heel and the metatarsal heads, while the lowest pressure distribution was under the cuboid bone and navicular bone.

The pressure distribution in anatomical area related to toe (mask 1) was the lowest in pescavus subjects (2.9 ± 0.6 N/cm2 in pescavus subjects vs. 4.7 ± 2.7 N/cm2 in the control group, $P < 0.05$).

Additionally, the pressure distribution in anatomical area related to the navicular bone (mask 3) was reduced, on average, by 59.4% in pescavus subjects (6.5 ± 1.5 N/cm2 in the control group, vs. 2.7 ± 0.9N/cm^2 in pescavus subjects, $P < 0.05$).

The pressure distribution was higher by 55.5% for the cuboid bone (mask 4) in the pesplanus subjects than in the control group (4.3 ± 1.7 N/cm^2 in the pesplanus subjects vs. 2.8 ± 0.5 N/cm^2 in the control group, $P < 0.05$).

For diabetic foot subjects without neuropathy, there is no statistically significant difference observed between this group and the control group.

So the highest pressure amplitudes were found under the heel and the metatarsal heads, while the lowest pressure distribution was under the cuboid bone and navicular bone.

Table (2): The time of foot contact area for the pesplanus, pescavus,and diabetic foot without neuropathy versus control subjects during walking (±SD).

Foot area	Normal foot	Pescavus	Pesplanus	Diabetic foot without neuropathy
1	0.12 ± 0.04	0.43 ± 0.02	0.08 ±0.05	0.12 ± 0.03
2	0.32 ± 0.06	0.58 ± 0.03	0.31 ± .07	0.33 ± 0.05
3	0.32 ± 0.11	0.39 ± 0.04	0.52 ±0.12	0.31 ± 0.12
4	0.17 ± 0.05	0.48 ± 0.02	0.41 ±0.13	0.18 ± 0.02
5	0.33 ± 0.08	0.41 ± 0.01	0.28 ±0.06	0.34 ± 0.09

Table 2 summarizes the time of foot contact area for the pesplanus, pescavus, and diabetic foot without neuropathy versus control subjects during walking.

No statistically significant differences were observed between control, pesplanus, pescavus, and diabetic foot subjects without neuropathy the time of foot contact (T) in anatomical area related to navicular bone (mask 3) and the heel (mask 5).

The time of foot contact was, on average, by 266% longer under toes (mask 1) in pescavus subjects (0.12 ± 0.05 sec. in normal subjects vs. 0.43 ± 0.02 sec. in pescavus group, $P < 0.05$).

Finally, the time of foot contact was, on average, by 133% longer under cuboid bone (mask 4) for pesplanus subjects (0.17 ± 0.05 sec. in normal subjects vs 0.41 ±0.13in pesplanussubjects, vs. 0.48 ± 0.02sec. in pescavus group, $P < 0.05$).

Among the diabetic foot without neuropathy subjects, no significant variations in the pressure, foot contact area, and time of foot contact area between this group and control group were found. In pathological subjects, such as the pesplanus and the pescavus the pressure varied depending on the type and location of the pathology.

DISCUSSION

Pedobarografic method indicates the changes in the distribution of plantar pressure with the increases and decreases of pressure in certain regions of the foot. Several studies have reported that plantar pressure distribution is useful to determine the abnormal walking pattern in cases of foot dysfunction as: rheumatoid foot, diabetic neuropathy, cerebral palsy, flat foot and clubfoot[7,8,14].

Most of the previous studied were conducted on each disease of the foot as pescavus, pesplanus, diabetic foot separated without comparison between them in separated study[3,18].

Our study proved that in normal subjects, the hind foot (heel) was the first part of the foot receiving the weight bearing of the body. Then it moved to the toe through the midfoot and the metatarsal area.

The highest mean pressure in normal subjects was found posterior in the hind foot under the heel and then anterior under the metatarsal heads. The lowest pressure distribution was under the cuboid bone.

The highest mean plantar pressure distribution in the flat foot subjects was found under cuboid bone (the middle of the foot) compared to normal subjects.

This finding is confirmed by the results reported by Szczygiel et al., 2008[17], who analyzed the difference in the distribution of pressure on the surface of the sole of a correctly arched feet and flat feet in 22 subjects aged between 10 and 20 years. They demonstrated that the pressure distribution on the soles of pesplanus subject was concentrated in the middle of the foot.

The mean of plantar pressure distribution in the high arched foot subjects or pescavus was lower under all parts of foot. The highest mean of plantar pressure distribution in the diabetic foot without neuropathy was found under both forefoot and rear foot.

Conclusion

The measurement of foot pressure distribution proves to be useful for the assessment of foot and gait pathologies. The dynamic plantar pressure distribution seems to be an important parameter which provides information about changes in human posture during walking. The pressure measurement during subject's standing gives also an important information on the loading of human body on foot in persons that suffer from various postural deformities.

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الملخص العربي

قياس توزيع الضغط الواقع من الجسم البشرى على باطن القدم في الأشخاص البالغين الذين يعانون من القدم المسطحة المرنة –القدم المقوسة العالية – القدم السكري الغير مصحوبة ب التهاب الأعصاب الطرفية – مقابل الأشخاص الطبيعيين

يهدف البحث إلى دراسة توزيع الضغط الواقع من الجسم البشرى على باطن القدم في الأشخاص البالغين الذين يعانون من القدم المسطحة المرنة –القدم المقوسة العالية – القدم السكري الغير مصحوبة ب التهاب الأعصاب الطرفية – مقابل الأشخاص الطبيعيين وذالك باستخدام جهاز قياس الضغوط الواقعة على باطن القدم في معمل التحليل الحركي أثناء السكون والحركة . أجريت الدراسة على ستين شخص وتم تقسيمهم إلى أربعة مجموعات متساوية تتكون كل مجموعة من خمسة عشر شخصا . المجموعة الأولى وهم الأشخاص الذين يعانون من القدم المسطحة المرنة ،المجموعة الثانية من الأشخاص الذين يعانون من القدم المقوسة العالية ، المجموعة الثالثة من الأشخاص الذين يعانون من القدم السكري الغير مصحوبة بالتهاب الأعصاب الطرفية ،المجموعة الرابعة من الأشخاص الطبيعيين .