Egyptian Journal of Physical Therapy (EJPT)

Egy. J. Phys. Ther. 2023;15:12-17

Original article

https://ejpt.journals.ekb.eg

Effect of Gender on Plantar Pressure Distribution in Normal Adults

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Published online:
Sept 2023

Abstract:
Purpose: to determine how gender affects the distribution of planter pressure in healthy adult individuals.
Methods: A total of 1,500 healthy individuals from both sexes (700 men and 800 women) participated in the study. They were chosen through campus recruitment. They were between the ages of 18 and 25. Two groups were formed out of them. The foot lab was used to measure planter pressure distribution by Zebreis Medical GmbH, Germany). Unpaired t-test and Spearman correlation coefficient was used to find the relation between gender and planter pressure distribution. Data analysis was done using the statistical package for social sciences computer program (version 20 for Windows; SPSS Inc., Chicago, Illinois, USA). Statistical significance was set at $P<0.05$.
Results: The two groups did not significantly differ from one another ($P<0.05$).
Conclusion: In healthy adults, gender has no effect on the distribution of planter pressure.
Key words: planter pressure, gender, foot biometric.

1. Introduction:

The anatomical and physiological differences between males and females are significant. (1,2). These differences result in different rates of lower extremity musculoskeletal injury amongst them. (3). The foot structure's deviation is believed to be a crucial element that will lead to issues with other body parts (diseases of the knees, lower back pain, etc.) (4) and highly elevated danger of lower limb malformations include flexible pes planus, pes cavus, limited dorsiflexion of the ankle, and increased inversion of the hindfoot (5).

Plantar pressure measurements while standing, walking, or performing other exercises can show how an atypical foot functions and provide an objective measurement of the plantar pressure distributions (6).

Skeletal anomalies that are visible on radiological examination may provide the opportunity to predict some of the change in plantar pressure based solely on structural elements (7,8).

The plantar weight distribution has been found to be useful in identifying gait irregularity in a number of research on foot biomechanics (6,9,10).

In recent years, measurements of plantar foot pressure have been widely used (1,11). "Force per unit area given in a right angle to a surface of an object" is the definition of pressure (12).

As a result, a number of factors, including the subject's weight, the contact surface, and the subject's speed at the time of ground contact, can affect plantar pressure. However, these factors can be balanced by the mechanical characteristics of the plantar soft tissue (13,14). Furthermore, it is widely known that a number of factors, such as the anatomical design of the foot, affect plantar pressure values (15).

The distribution of the foot's load is altered by even minor changes to its anatomy (16). Then, other studies looked at possible variations in plantar pressure distribution between adults based on gender orientation. Mechanical discomfort is thought to be exacerbated by abnormally elevated plantar pressure, and aberrant plantar pressure distribution may signal biomechanical imbalance (17,18).

The size of the foot, both in absolute and relative terms, is lower in females when stature is taken into account, which is another description of gender-specific differences in foot shape and structure. Additionally, it has been claimed that the sexual dimorphism in the foot's bones, such as the talus, calcaneus, metatarsals, and phalanges, facilitates the gender identification in forensic investigations. Males were also shown to have considerably greater contact areas, force-time integrals under the heel, first and third metatarsal heads, and mean forces under the third metatarsal head than females (2Demirbüken et al., 2019 stated that adolescent male and female total plantar pressure distribution showed that there were substantial disparities (19).

Setting up standardized data would make it easier to define appropriate treatment goals and diagnose pathologic situations (19).

Therefore, the investigation's main goal was to look into potential variations in adult male and female plantar pressure distributions when they are standing.

2.Patients and Methods:

An observational cross-sectional study was performed to examine changes in the plantar pressure distribution under the soles of the feet in healthy adult male and female subjects. This study was carried out in the foot planter pressure monitoring unit at Misr University for Science and Technology (Zebreis Medical GmbH, operating instructions Germany, 2007).

2.1. Participants:

A total of one thousand and five hundred average participants were enlisted from the university's campus. The participants were split into two groups based on their gender, with 700 men and 800 women in each group. Their ages ranged from 18 to 25 years, and their BMIs ranged from 19.22 to 29.4 kg/m2. Every participant underwent a primary check-up to get a full picture of their health, find out if there were any contraindications, and decide if they could take part in the study.

Further exclusion criteria included having: (1) a history of foot or ankle trauma; (2) musculoskeletal, lymphatic, or vascular injury; (3) a cancer; (4) a genetically inherited malformation; (5) a neuromotor disorder; (6) aches and pains in the ankle or foot; and (7) any other problem that might restrict the subjects' ability to move around. All individuals had signed written informed consents before participation in the current study. The human research and ethical committee at Misr University for Science and Technology gave its approval to the ongoing study.

2.2. Instrumentation:

2.2.1. Measurement equipment and tools

2.2.1. Using a Stadiometer to measure height:

In either bare feet or stockings, the individual was instructed to stand upright with heels touching and feet tilted at around 60°. The buttocks or back were kept in contact with the wall or the Stadiometer when it was in use. The participants were instructed to keep their feet flat on the ground while actively stretching to a fully upright position with their heads in the "Frankfort plane" and looking straight ahead. The measurement device's horizontal arm was carefully lowered until it compressed the hair as much as possible and maintained a hard right angle to the scale (20).

2.2.2. Force distribution measuring system (FDM-S):
The static plantar pressure distribution of both feet was measured using the FDM-S measuring platform by the force distribution measurement system (Zebreis Medical GmbH, Germany) (30).

System components:

1. Platform measurements (length 60cm - width 38cm –height 2.1cm, weight 4.5kg)
2. There are 1536 sensors, with a 48 cm by 32 cm sensor area.
3. Power supply component
4. User software application, IBM – with at least Pentium IV. 5- HB printer to print the test results (Manual of FDM - S measuring platform-Zebris, Gmbh, operating instructions, 2007).

2.2.3. Weight measurement by weighting scale:

As the individual stands over the center of the platform with their weight evenly divided between both bare feet, ask them to wear light clothing and then read the measurement in kilograms (21).

2.3. Procedures of the study:

The participants were told to stand on the platform with their feet slightly apart, relaxed in the anatomically correct upright position, and to try to place them in the middle of the two perpendicular lines. To lessen the sway factor, the instrument will define the right and left feet for 20 seconds prior to the recording. The computer will then generate the plantar pressure measurements. The foot pressures operating on each plate sensor were expressed in Newton per square centimeter. The percentage values, light and dark shadows, and forefoot, hind foot, and total % of feet are shown in **Figure (1)** as the force distribution between both feet (Manual of FDM – S, Zebreis Medical GmbH, operating instructions Germany, 2007).

Data analysis:

The data was displayed as mean and SD. Shapiro-Wilk and Kolmogorov-Smirnov tests were used to check the data for normality, and the results revealed that all measured variables have a normal distribution. Comparison between mean values of subjects characteristics of the two groups (Males and Females groups) and between the measured variables was performed using unpaired t-test. Spearman correlation coefficient was used to find the relation between gender and planter pressure distribution. Data analysis was done using the statistical package for social sciences computer program (version 20 for Windows; SPSS Inc., Chicago, Illinois, USA). Statistical significance was set at P<0.05.

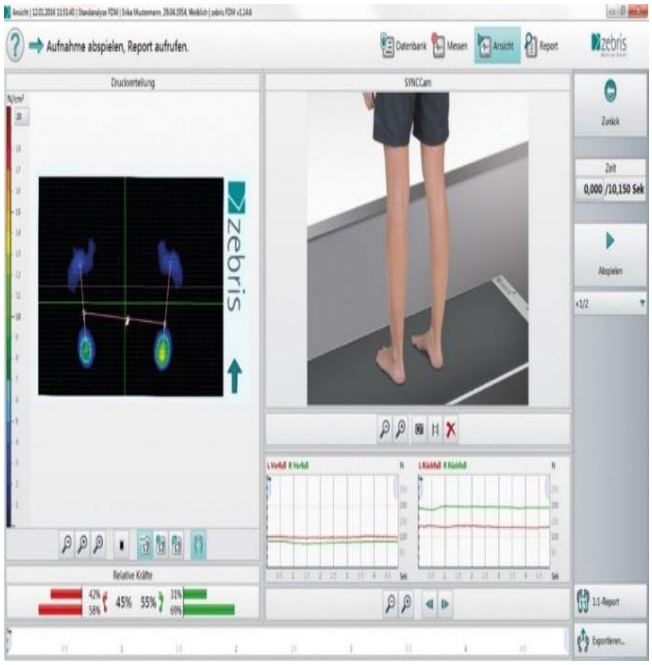

Figure (1): Manual of FDM - S measuring platform-Zebris, Gmbh, operating instructions, 2007

3.Results:

General Characteristics of the Subjects:

1500 subjects' data were gathered, and they were divided into two separate groups.

Males group:

There were 700 of them, and their average ages, weights, heights, and body mass index (BMI) were (19.14±0.7) years, (72±8.73) kg, (167.2±5.6) cm and (25.1±2.2) kg/m2 respectively.

Females group:

The average age, weight, height, and BMI of 800 females were (18.37±0.91) years, (63.7±11.6) kg, (161.6±4.3) cm and (24.5±3.1) kg/m2 respectively. The age, height, weight, and body mass of the two groups did not significantly differ from one another (BMI) (p > 0.05) as shown in **table (1).**

Table (1): General Characteristics of subjects in both groups

General characteristics	Males group Mean ±SD	Females group Mean ±SD	t-value	P-value
Age (yrs.)	19.14 ±0.7	18.37 ±0.91	1.84	0.088
Weight (kg)	72±8.73	63.7±11.6	1.569	0.141
Height (cm)	167.2±5.6	161.6±4.3	2.15	0.054
BMI (kg/m2)	25.1±2.2	24.5±3.1	0.461	0.653

***SD: standard deviation, P: probability**

I- Effect of gender on plantar pressure distribution:

Males group:

The mean ± SD of right fore foot, hind foot and total foot were 32.3±13.7, 67.7±13.7 and 49.9±0.9 respectively. While the mean ± SD of left fore foot, hind foot and total foot were 34.6±13.4, 65.3±13.4 and 50.1±0.93 respectively.

Females group:

The mean ± SD of right fore foot, hind foot and total foot were 37.4±23, 62.6±23.4and 49.2±2.65 respectively. While the mean ± SD of left fore foot, hind foot and total foot were 38.2±22, 61.8±22.1 and 50.8±2.65 respectively.

Comparing the two groups:

There was no significant variation in the mean values of right and left fore foot, hind foot and total foot between both groups (p > 0.05). (**Table 2**).

Table (2): Comparison between the mean of measured variables of both groups

Measured variables	Males group Mean ± SD	Females group Mean ±SD	Percent of difference	t-value	P-value
Right Fore foot	32.3±13.7	37.4 ±23	15.8%	-0.501	0.625
Right hind foot	67.7±13.7	62.6±23.4	8.1%	0.501	0.625
Total right foot	49.9±0.9	49.2±2.65	1.4%	0.722	0.483
Left Fore foot	34.6±13.4	38.2±22	10.4%	-0.372	0.716
Left hind foot	65.3±13.4	61.8±22.1	5.7%	0.372	0.716
Total Left foot	50.1±0.93	50.8±2.65	1.6%	-0.722	0.483

II- Relationship between gender and plantar pressure distribution:

Weak positive non-significant correlations were found between gender and the right forefoot's plantar

pressure distribution (r = 0.015, p = 0.956). While there were only minor, non-significant negative relationships between gender and the right hind foot (r = -0.015, p = 0.956) and the entire right foot showed weak, insignificant, negative relationships (r = -0.294, p = 0.287).

Weak negative non-significant correlations were found between gender and the left forefoot's plantar pressure distribution (r = -0.108, p = 0.701). While there were only minimally positive, insignificant relationships between gender and the left hind foot (r = 0.108, p = 0.701) and the entire left foot showed weak, insignificant, negative relationships (r = 0.294, p = 0.287) (**Table 3**).

Table (3). Correlation between gender and plantar pressure distribution

Planter pressure Distribution and gender	r value	p value
Right Fore foot	0.015	0.956
Right hind foot	-0.015	0.956
Total right foot	-0.294	0.287
Left Fore foot	-0.108	0.701
Left hind foot	0.108	0.701
Total Left foot	0.294	0.287

r value=Spearman correlation coefficient;
p value=Probability value

III- Relationship between body mass index (BMI) and plantar pressure distribution:

The relationship between BMI and plantar pressure distribution of the right fore foot was weak negative non-significant correlations (r = -0.266, p = 0.337). While between BMI and right hind foot was weak positive non-significant correlations (r = 0.226, p = 0.337) and of the entire right foot showed only weakly positive, insignificant relationships (r = 0.359, p = 0.188).

The relationship between BMI and plantar pressure distribution of the left fore foot was weak negative non-significant correlations (r = -0.277, p = 0.318). While between BMI and left hind foot was weak positive non-significant correlations (r = 0.277, p = 0.318) and of total left foot was weak negative non-significant correlations (r = -0.359, p = 0.188) (**Table 4**).

4. Discussion:

The goal of this study was to examine whether the distribution of planter pressure in the standing positions of normal adult males and females differs. The results of this investigation showed that there was no significant difference between the two groups in the mean values of the right and left forefoot, rear foot, and total foot and this in agree with **Abboud et al. (2000)** who stated that In healthy, normal feet without pain or any anatomical or functional abnormality, adequate plantar stress distribution occurs under the load-bearing portions of the foot, such as the heel, metatarsal heads, and phalanges of the toes (22).

Table (4): Correlation between BMI and plantar pressure distribution

Planter pressure distribution and BMI	r value	p value
Right Fore foot	-0.266	0.337
Right hind foot	0.266	0.337
Total right foot	0.359	0.188
Left Fore foot	-0.277	0.318
Left hind foot	0.277	0.318
Total Left foot	-0.359	0.188

r value=Pearson correlation coefficient;
p value=Probability value

Another study by **Murphy et al. (2005)** found no significant differences between males and females in the normalized midfoot contact region or plantar pressure values(23). Another study revealed no gender differences in over-pressure, contact time, stress-time summation, or moment of over-pressure, despite male responders having greater contact areas, pressure-time integrals, and maximum forces in some particular regions (2).

On the other hand, **Koo et al. (2018)** found that compared to female subjects, male individuals showed higher peak pressure on the forefoot and a pressure-time integral on the medial forefoot and heel. While female subjects showed more dorsiflexion during stride and thinner plantar soft tissue than male ones (19).

In a study by **Periyasamy et al. (2011)**, they used edoPowerGraph plantar pressure measurement system for the formation of the standing foot pressure image, a digital camera for picture capture, a TV tuner PC add-on card, WinDvr software for still capture, and Matlab software with specialized image analysis methods for determining the difference between men and women in the foot pressure distribution parameter, or power ratio (1).

Additionally, **Chung et al. (2012)** reported that the overall plantar pressure distribution of adolescence

showed that there were noticeable disparities between male and female, especially at the age of 14. Male total contact area began to rise between the ages of 11 and 14. The distribution of planter pressure for males compared to females may have differed significantly as a result of this increase in contact area due to their larger feet, men adults were found to have a larger contact area than their female counterparts in prior research (24).

Yamamoto et al. (2020) conducted a study to investigate the sex-related differences in plantar stress distribution during activities, ten plantar pressure sensors were embedded in a 1-mm thick insole, measuring a total of 29g. They discovered that during standing and walking activities, healthy women had greater plantar compressive forces in the forefoot than did men (29).

Additionally, neither group's BMI nor planter pressure distribution showed a discernible difference and this was in agreement with **Hennig and Milani (1993)**, **Clarke and Cavanagh(1981)** who discovered that there was little association between body weight and the peak pressures beneath the feet in persons of normal weight and that suggested that the lack of a correlation between weight and maximum pressures was attributed to greater foot contact area during the stance phase of gait or the distribution of heavy loads to wider anatomical areas of the foot (25, 26).

However, in a study of 19 people, where weight was balanced by adding known weights to a vest, there were considerable increases in mean peak plantar foot pressures beneath the same anatomical locations of interest (27).

While Hills et al. (2001) provided the essential facts about the functional restrictions related to both passive (standing) and active (walking) circumstances with regard to foot mechanics. The structural implications of repeated stress on the foot and other lower limb components are important to consider given the noticeable changes in plantar pressures brought on by elevated body mass index (BMI) (28).

Limitations:

The inclusion of a blind researcher was a drawback of the current study, so we recommend further investigation into this issue as well as the bias in sample selection caused by the lack of randomization.

Conclusion:

According to the study's findings, there are no gender-related differences in the planter pressure distribution in healthy adult males and females. This finding suggests that normal subjects follow a pressure distribution pattern from the heel to the forefoot regardless of their gender, and any deviation from this pattern may help detect pathology associated with an orthopedic disorder.

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