# Relationship between regional plantar pressure and balance calculated by pedobarography in healthy young individuals: comparing the gender and bodyweight

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**Abstract**. The aim of the study is to examine the relationship between regional plantar pressure values and balance parameters in healthy young individuals by comparing them according to gender and body weight.
Within the scope of the research, plantar pressure analysis was applied to 47 students (average age 21.78±1.94 years) studying at the Faculty of Health Sciences in Biruni University. In addition to static and dynamic pressure analysis with the pedobarography device, body mass index and balance were also evaluated, antero-posterior, medio-lateral and static total balance scores were calculated. When the relationship between plantar pressure averages and balance parameters in the fore, hind and midfoot were examined, the most significant correlation was observed between antero-posterior balance and forefoot pressure ($r=0.499$, $p<0.001$). In addition, it was observed that there was a significant correlation between the mean pressure with the hind foot and the static balance parameters ($r=0.373$; $p<0.05$). According to the results of the intergroup comparisons, it was concluded that the plantar pressure values in the forefoot of women and midfoot of men were statistically significantly higher ($p<0.05$). As a result of the analysis based on bodyweight, it was concluded that the forefoot plantar pressure values of individuals with normal weight and the midfoot plantar pressure values of overweight-obese individuals were significantly higher ($p<0.05$). Also, the relationship between the load distribution ratio and the forefoot and midfoot pressure obtained in healthy individuals can be considered as an important reference. In addition, it was concluded that the amount of pressure in the heel area during standing and walking is an important variable affecting the static balance. Finally, plantar region comparisons based on gender and bodyweight provide important data.
**Key words:** *plantar pressure, balance, pedobarography, healthy youngest, bodyweight.*

## Introduction

The foot is an important part of the locomotor system which connects the lower limb to the spine via the pelvis (1). The foot performs important tasks such as absorbing shock, adapting to different surfaces and producing the necessary moment for walking by providing contact with the support surface in all weight-bearing activities. Although it is known that foot problems are very common in the general population, it has been reported that the incidence of foot problems in individuals over the age of 18 is 24%, and the incidence of foot pain in individuals between the ages of 18-45 is around 10% (2).

Plantar pressure analysis has been used in various studies to detect foot pathologies. These studies have identified the pressure characteristics during gait, contact area of the foot and the forces produced. These systems can be used for detecting gait and balance abnormalities, classifying the foot types, designing foot orthoses and insoles, and assessing the success of corrective foot surgery (3).

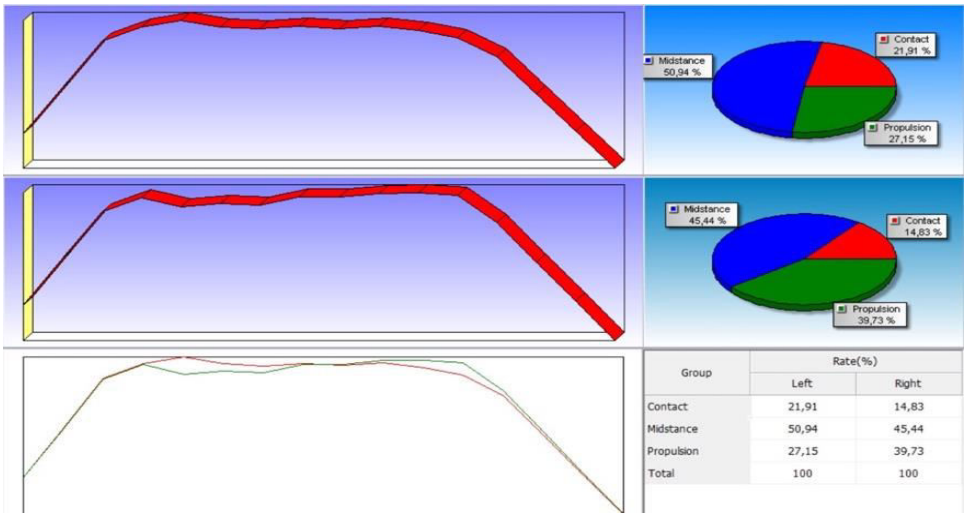
High pressure areas are associated with different pathomechanics such as diabetic ulcer, forefoot rheumatoid arthritis, hallux valgus deformity, medial midfoot osteoarthritis, and pes planus due to posterior tibial tendon dysfunction. When foot bones are not properly distributed, the body weight is unevenly applied to the sole, thereby resulting in various symptoms. Important variables for walking such as foot angle, weight transfer rates, force and center of gravity can also be calculated by plantar pressure analysis method. Thus, a general foot biomechanics profile can be created (4, 5).

The medial longitudinal arch (MLA) of the foot is an important anatomical formation that performs the functions of shock absorption and load transfer during standing and walking. Changes in the height of the MLA directly affect the plantar pressure distribution. In particular, the area and pressure percentage parameters of the midfoot region are associated with the height of the MLA. The height of the arc is realized from the navicular projection, which is the highest point of this structure. An increase in arch height indicates pes cavus, and a decrease indicates pes planus deformity. Decreased MLA height will cause an increase in midfoot plantar pressure percentage, and an increase in MLA height will cause a decrease in midfoot plantar pressure percentage (6, 7).
Balance is the ability to keep the body in static position or maintain the upright position while standing or sitting. The evaluation of balance provides essential information concerning the efficiency of the locomotor system. Measures of center of pressure sway behavior recorded from force platforms are considered the gold standard for assessing balance performances, by providing unique information (8). Proper function of lower limbs requires both normalization of balance and symmetrical distribution of loads (9).
Since gait and balance are functions that are closely related to each other, evaluating them together using pedobarography technology will enable to reach important data (10-12).
The aim of the study is to examine the relationship between regional plantar pressure values and balance parameters in healthy youngest by comparing them according to gender and body weight variables.

## Material and Method

*Study design and Participants:* Within the scope of this research 47 healthy university students (14 males; 33 females) with a mean age of 21.78±1.94 years were included. All participants were 3rd year students in physiotherapy and rehabilitation department. Average BMI scores of the participants was 22.25±3.91 kg/m$^2$.
*Inclusion criteria:* Individuals who did not have any orthopedic problems that could prevent standing and walking activities in their lower extremities and who did not have wounds, ulcers, calluses, etc. formations in the plantar region were included in the study. *Exclusion criteria:* Individuals with standing and balance problems, using orthoses for walking, and who had undergone lower extremity surgery in the last 1 year were excluded from the study. Patients with pes planus with a navicular drop test result of 10 mm or more were excluded from the study.
Measurements were made in over a period of 3 months during August-October 2021. Ethical approval was received from Biruni University Ethics Committee: dated 30/07/2021, number 2021/57-7.
*Demographic Information Form:* It contains information such as age, gender, body mass index. This information is recorded in software directly connected to the pedobarographic device.
*Foot Checker Pedobarographic Device:* Plantar pressure evaluations were carried out in Biruni University Biomechanical Laboratory. The GHF550 Foot Checker Pedographic Device was used for the analyses. The sensor layer located on the pressure platform of the pedobarography device (Fig. 1) provides the detection of the regional weight transfer of the foot during the walking phases (Fig. 2). With the findings obtained, objective data about regional average plantar load and percentage, antero/posterior (A/P) and medio/lateral (M/L) and static total balance variables are obtained (Fig. 3).

**Figure** 1. Pedobarography device




| Group | Rate(%) | |
|---|---|---|
| | Left | Right |
| Contact | 21,91 | 14,83 |
| Midstance | 50,94 | 45,44 |
| Propulsion | 27,15 | 39,73 |
| Total | 100 | 100 |

**Figure** 2. Regional loading during gait phases

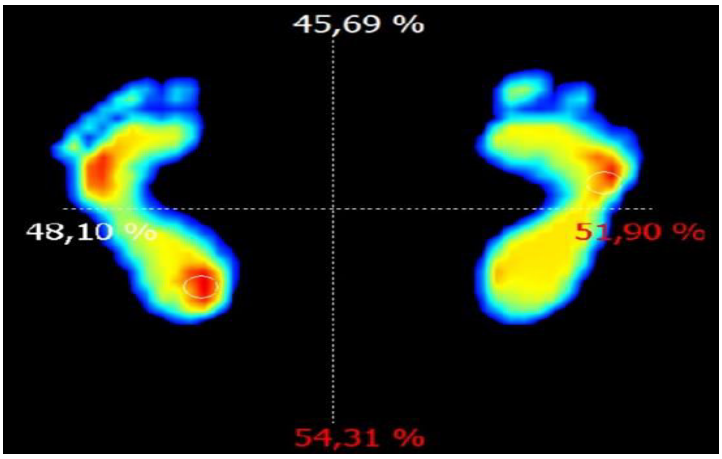



**Figure** 3. Anteroposterior and mediolateral balance percentages

During static analysis, the subjects were asked to placed their feet on the pedobarography device in standing position. During dynamic analysis participants were asked to pass over the pedobarography platform (5, 6) (Fig. 4).

**Figure** 4. Dynamic plantar pressure analysis

*Statistical analysis.* For the analysis of the plantar region, it was divided into three areas as forefoot, midfoot and hindfoot. The mean and standard deviation of plantar pressure percentages were calculated for all areas. The correlation between Forward/backward and left/right balance and BMI, static total pressure and regional plantar pressure variables were calculated. Pearson's Correlation Coefficient were used to measure the statistical relationship between the plantar pressure variables of all participants. Mann Whitney U test was used for intergroup comparisons.

## Results

When the regional plantar pressure averages and balance parameters were compared; the correlations between balance, BMI and pressure variables had correlation coefficient r values ranging from 0.373-0.499. Each correlation shown in Table I is significant ($p<0.05$). The most significant correlation coefficient was found between A/P balance and forefoot average pressure (r=0.499). Negative correlations are between A/P balance and BMI (r=-0.406); A/P balance and midfoot average pressure (r=-0.443). Static total balance correlated with hindfoot average pressure (r=0.373). There was no relationship between A/P balance and hindfoot average pressure. Statistical analysis results based on plantar data are as follows: According to the results of the Mann-Whitney U test performed according to gender, it was concluded that the plantar pressure values in the forefoot of women and midfoot of men were statistically significantly higher ($p<0.05$). There was no difference between the sexes in the hind foot (Table II).

**Table** I. The relationship between regional plantar pressure, BMI and balance variables

| **Variables** | | **BMI** | **Forefoot average pressure** | **Midfoot average pressure** | **Hindfoot average pressure** |
|---|---|---|---|---|---|
| **A/P balance** | r | -0.406 | 0.499 | -0.443 | |
| | p | 0.005 | 0.000 | 0.002 | |
| **Static total balance** | r | | | | 0.373 |
| | p | | | | 0.010 |

*A/P: Anterior/posterior; BMI: Body Mass Index*

**Table** II. Comparison of regional plantar pressure averages by gender

| **Region** | **Males** | | **Females** | | *p* |
|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | |
| Forefoot | 44.89 | 2.30 | 48.69 | 3.28 | 0.001 |
| Midfoot | 31.10 | 2.21 | 27.40 | 4.30 | 0.005 |
| Hindfoot | 24.03 | 2.24 | 23.95 | 2.49 | 0.798 |

As a result of the analysis based on weight, it was concluded that the forefoot plantar pressure values of individuals with normal weight and the midfoot plantar pressure values of overweight-obese individuals were significantly higher ($p<0.05$). There was no difference in terms of different weight values in the hind foot (Table III).

**Table** III. Comparison of regional plantar pressure averages by weight

| **Region** | **Normal-weight** | | **Overweight/obese** | | *p* |
|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | |
| Forefoot | 48.42 | 3.34 | 46.18 | 3.18 | 0.027 |
| Midfoot | 27.51 | 4.05 | 30.09 | 4.02 | 0.032 |
| Hindfoot | 24.03 | 2.71 | 24.00 | 1.56 | 0.816 |

## Discussion

When the results of plantar pressure analysis performed on university students were examined, it was seen that remarkable results were obtained between the balance and pressure parameters. There are not many studies in the literature examining the relationship between balance and plantar pressure. In order to reach definite judgments about plantar pressure analysis, first of all, it is necessary to analyze and define the variables in the healthy foot structure correctly.

According to the Barbosa et al. study on the ability to maintain balance in the daily activities of low and high BMI groups, the high BMI group showed decreased ability to maintain balance (13). In our study, the deterioration of A/P is thought to be compensated by the increase in midfoot pressure.

Decreased medial longitudinal arch height could affect antero-posterior balance. In addition, the altered anteroposterior balance not only causes a decrease in medial longitudinal arch height, but also causes problems with the mechanoreceptors of the foot. A study by Handrigan et al reported that increased weight can decrease the quality of proprioceptive information necessary for balance by putting excessive weight above the detection threshold on the foot's mechanoreceptors (14-16).

It was observed that below normal feet, the pressure is slightly higher on the heel than on the forefoot (17). The amount of pressure in the forefoot increases in structural foot disorders (18). In our study on a healthy young population, it was found that the static total balance increased as the pressure on the hind foot increased, as if supporting this situation.

In the study of Yamamato et al., it was revealed that the amount of forefoot plantar pressure in women is higher than that of men (19). In our study, a result supporting this situation was found, and it is thought that women's habit of wearing high heels may cause this. In terms of body weight, Youssef et al. In 2020, as in our study, it was observed that the midfoot pressures of overweight individuals were higher than those of normal weight (20). The main reason for this situation is the increase in the midfoot contact area as a result of the decrease in the medial longitudinal arch height due to weight gain.

## Conclusion

When the literature is examined, the complexity of the results is remarkable. In order to reach clear interpretations on this issue, studies in healthy population will help to better understand the nature of the phenomenon. Our research is one of the rare examples in terms of revealing the relationship between regional pressure and balance parameters.

As a result of the research, the significant relationship between the load distribution ratio between the fore and hind legs and the forefoot pressure obtained in healthy individuals can be considered as an important reference. In addition, it was concluded that the amount of pressure in the heel area during standing and walking is an important variable affecting the static balance.

*Study limitations:* Due to the technical problems we experienced during the research, we could not calculate the temporal parameters that are important for gait. In the next studies, we plan to measure pressure time integrals with the camera analysis method.

*Ethics Committee Approval***:** The Ethics Committee of Biruni University (Date: 30.07.2021; decision no: 2021/57-7). *Conflict of Interest:* No conflict of interest was declared by the authors.

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