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The effect of age and gender on foot pressure distribution: A cross-sectional case-control study using static analysis

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Abstract

This study aims to investigate the effects of age and gender on static foot pressure distribution. Foot pressure distribution is known to be associated with biomechanical properties, postural stability, and load transfer. The study included two groups: young adults aged 18–35 years and individuals over 35 years. Participants were assessed using static pedobarography, and average pressure, maximum pressure, contact area, and the percentage of load on the forefoot and rearfoot were analyzed. Differences between genders were also examined. The data showed that age has a significant effect on foot pressure distribution. As age increased, the percentage of load on the forefoot increased, while the load on the rearfoot decreased (p=0.003). Women had significantly higher average pressure (p=0.001) and maximum pressure (p=0.026) on the right foot compared to men. However, men exhibited a larger contact area (p=0.000). While no significant difference was found between genders in terms of forefoot and rearfoot load distribution, a significant difference in forefoot load percentage was observed between the age groups (p=0.007). The findings suggest that age is a significant determinant of foot pressure distribution, with load tending to shift toward the forefoot with increasing age. Gender influences certain pressure parameters but does not result in a significant difference in load distribution. These results highlight the importance of considering age-related postural changes and gender differences in rehabilitation strategies.

Keywords: Static foot pressure analysis, age, gender, pedobarography, biomechanics

Introduction

Walking and postural balance are among the fundamental motor skills necessary for performing activities of daily living. As the sole structure in contact with the ground and responsible for bearing body weight, the foot plays a critical role in biomechanical load distribution. Static foot pressure analysis is a commonly used method to evaluate weight distribution during standing and to determine the effects of factors such as age and gender on this distribution. Although previous studies have suggested that age and gender may influence foot loading patterns, the specific effects of these variables on pressure distribution remain a subject of debate [1,2]. Therefore, investigating the effects of age and gender on static foot pressure parameters is crucial for understanding individual postural stability and improving clinical approaches.

Foot pressure distribution is directly related to musculoskeletal changes associated with aging, postural adaptation mechanisms, and gender-based biomechanical differences [3,4]. Given the potential impact of age-related changes in foot pressure distribution on fall risk, balance disorders, and gait patterns in older adults, this issue warrants further investigation. Additionally, understanding the impact of gender on foot pressure values can inform clinical applications across a wide range of populations, from athletes to older adults.

Pedobarography is widely used in scientific and clinical research as an objective tool to evaluate plantar pressure distribution. It provides valuable information for the assessment of balance, gait patterns, musculoskeletal disorders, and rehabilitation outcomes [7,8].

This study aims to evaluate the effects of age and gender on static foot pressure distribution. By analyzing forefoot and rearfoot pressure percentages, total contact area, and maximum pressure

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values among individuals of different age groups, the study explores how aging may alter foot pressure patterns. Furthermore, the study examines the effects of gender on these parameters to identify potential differences between male and female participants. Our goal is to contribute to a better understanding of the relationship between aging and foot loading patterns, and to support the development of personalized approaches in rehabilitation. By analyzing the influence of age and gender on foot pressure distribution, this study aims to provide new data to the existing literature and contribute to clinical decision-making and individualized assessment processes.

Hypotheses

1. Foot pressure distribution differs significantly across age groups.
2. There are significant differences in foot pressure distribution between males and females.

Material and Methods

Participants and Assessment

Healthy individuals aged 18 years and older who applied to the Department of Physical Medicine and Rehabilitation were included in the study. Evaluations were conducted in a single session, during which demographic data were recorded. Static pedobarographic measurements were used to analyze parameters such as average pressure, maximum pressure, contact area, and the distribution of load between the forefoot and rearfoot. The study population was divided into two groups: young adults aged 18–35 years (Group 1) and individuals over 35 years (Group 2).

The study received ethical approval from the Biruni University Clinical Research Ethics Committee Ethics Committee (Approval Number:2015-KAEK-80-23-46) (Approval Date: 22.12.2023).

Inclusion Criteria

Participants included in the study were individuals aged 18 years or older, able to stand unaided, with normal foot anatomy [9], and who volunteered to participate.

Exclusion Criteria

Individuals were excluded if they had any neurological or musculoskeletal disorders that could affect balance or foot pressure distribution; were pregnant; used any prosthetic or orthotic device; had incomplete or faulty foot pressure data; exhibited significant cognitive impairment; or had mental, visual, or auditory impairments that could interfere with communication. Additionally, individuals with pronounced deviations in the sagittal, coronal, or horizontal planes during postural assessment, or with positive findings in the Adam's forward bend test or scoliometer screening, were excluded from the study.

Foot Pressure Measurement Procedure

Foot pressure measurements were conducted using a static pedobarography device (Amcube brand). This system records plantar pressure distribution while the participant is standing. During the assessment, participants stood barefoot on the device platform. To avoid balance disturbance and unintended weight transfer, participants were instructed to look at a fixed point located three meters away. The step width between the feet was standardized at 8 cm [10]. To ensure accuracy, measurements were repeated three times, and the average of the results was recorded (Figure 1).

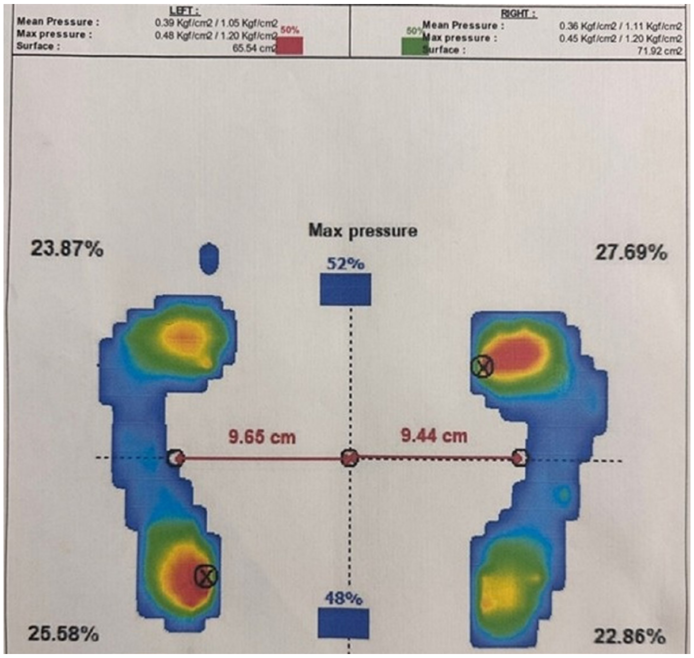

Figure 1. Outcome of static pedobarographic analysis

All participants provided written informed consent prior to their inclusion in the study.

Statistical Analysis

Descriptive statistics including mean, standard deviation, median, minimum and maximum values, frequency, and percentages were used in the analysis. An independent samples t-test was used to compare demographic variables, while foot pressure parameters were analyzed using the independent two-sample t-test. The distribution of variables was assessed using the Kolmogorov-Smirnov test. The Mann-Whitney U test was applied for non-normally distributed independent quantitative variables. For categorical variables, the chi-square test was used for independent. A p-value of <0.05 was considered statistically significant, with a confidence interval of 95%.

Result

Table 1 presents a comparison of static foot pressure distribution between male and female participants. Women exhibited significantly higher average pressure ($p=0.001$) and maximum pressure ($p=0.026$) in the right foot compared to men. However, no significant differences were observed between genders in these parameters for the left foot ($p>0.05$). The contact area was significantly larger in men than in women for both feet (right

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foot: p=0.002; left foot: p=0.000).

Regarding load distribution, no significant gender differences were found in the percentage of load on the forefoot (p>0.05). However, the percentage of load on the rearfoot was significantly higher in men than in women for the left foot (p=0.004).

Table 2 compares the static foot pressure distribution parameters between Group 1 and Group 2. Regarding average pressure, higher values were observed in Group 2 for both the right and left foot, with statistically significant differences found in the right foot (p=0.004) and the left foot (p=0.001). No significant differences were detected between the groups in terms of maximum pressure (p>0.05).

When evaluating the contact area, Group 2 demonstrated a significantly larger surface area in both the right and left foot (p=0.000). The percentage of total load distributed to the forefoot was also significantly higher in Group 2 for both the right (p=0.003) and left (p=0.045) foot.

Table 3 examines the effects of age and gender on static foot pressure distribution. No significant difference was found between the groups in terms of gender distribution (p=0.845). There was no statistically significant difference between males and females in the percentage of load on the forefoot (p=0.818). However, when evaluated by age, Group 2 showed a significantly higher percentage of forefoot load (p=0.003). Correspondingly, Group 1 had a significantly higher percentage of rearfoot load (p=0.007).

No significant gender difference was observed in maximum pressure values (p=0.920). However, Group 2 exhibited a significantly higher maximum pressure on the forefoot compared to Group 1 (p=0.001).

Table 1. The effect of gender on foot pressure distribution

	Right Foot Mean+SD/(Min-Max)		p	Left Foot Mean+SD/(Min-Max)		p
	Female (n=81)	**Male (n=39)**		**Female (n=81)**	**Male (n=39)**	
Average Pressure (kgf/cm²)	0.5+0.1 (0.2-0.7)	0.4+0.1 (0.2-0.8)	**0.001**	0.5+0.1 (0.3-0.8)	0.5+0.1 (0.3-0.9)	0.128
Maximum Pressure (kgf/cm²)	1.6+0.4 (0.9-3.1)	1.5+0.3 (0.9-2.1)	**0.026**	1.7+0.4 (1.0-2.8)	1.7+0.4 (1.0-2.7)	0.906
Contact Area (cm²)	83.6+14.1 (42.3-122.4)	95.1+25.1 (42.9-142.5)	**0.002**	81.5+13.7 (42.3-117.7)	95.7+23.2 (48.7-135.7)	**0.000**
Forefoot Load (% of Total Load)	19.8+5.1 (8.1-29.8)	19.6+4.5 (12.4-26.9)	0.794	20.7+5.0 (10.7-37.8)	20.5+4.0 (10.8-33.9)	0.944
Rearfoot Load (% of Total Load)	29.1+6.2 (14.6-40.9)	26.2+7.9 (8.1-41.1)	0.065	33.30.1+5.9 (17.9-43.1)	33.6+5.8 (24.6-45.6)	**0.004**

Table 2. Foot pressure and load distribution parameters by age group

	Right Foot Mean+SD/(Min-Max)		p	Left Foot Mean+SD/(Min-Max)		p
	Group 1 (n=60)	**Group 2 (n=60)**		**Group 1 (n=60)**	**Group 2 (n=60)**	
Average Pressure (kgf/cm²)	0.4+0.1 (0.2-0.6)	0.4+0.1 (0.2-0.8)	**0.004**	0.4+0.1 (0.3-0.7)	0.5+0.1 (0.2-0.9)	**0.001**
Maximum Pressure (kgf/cm²)	1.6+0.4 (1.0-3.1)	1.6+0.4 (1.0-3.1)	0.711	1.7+0.4 (1.1-2.8)	1.7+0.4 (1.0-2.8)	0.398
Contact Area (cm²)	79.1+18.1 (42.3-129.9)	87.3+19.1 (42.3-142.5)	**0.000**	78.1+18.5 (42.3-135.7)	86.1+18.5 (42.3-135.7)	**0.000**
Forefoot Load (% of Total Load)	18.3+4.5 (8.1-28.9)	19.8+4.9 (8.1-29.8)	**0.003**	20.1+5.1 (10.8-37.7)	20.7+4.7 (10.7-37.7)	**0.045**
Rearfoot Load (% of Total Load)	29.6+5.5 (19.4-41.1)	28.2+6.9 (8.14-41.1)	0.198	32.0+5.3 (17.9-45.2)	31.2+6.1 (17.9-45.6)	**0.040**

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Table 3. Comparison of forefoot and rearfoot load percentages by age and gender

	n (%)/Mean+SD/(Min-Max)		p	n (%)/Mean+SD/(Min-Max)		p
	Famale	Male		Group 1	Group 2	
Age	38.1+17.9 (18-75)	39.9+19.0 (18-76)	0.371	22.7+4.3 (18-34)	54.7+11.3 (36-76)	
Gender (n. %) **Famele** **Male**	81 (68%)	39 (32%)		40 (33%) 20 (67%)	41 (32%) 19 (68%)	0.845
Forefoot Load (% of Total Pressure)	40.6+7.9 (24-62)	40.1+5.7 (25-48)	0.818	38.1+6.5 (24-50)	42.7+7.3 (30-62)	**0.003**
Rearfoot Load (% of Total Pressure)	59.4+7.9 (38-76)	58.6+7.9 (23-75)	0.502	61.0+8.1 (23-76)	57.3+7.3 (38-70)	**0.007**
Forefoot/Rearfoot Pressure Ratio	1.4+6.4 (0.3-58)	0.7+0.1 (0.3-0.9)	0.920	0.6+0.1 (0.3-1.0)	1.7+7.4 (0.4-58)	**0.001**

Discussion

In this study, the effects of age and gender on static foot pressure distribution were investigated. The findings revealed that foot pressure parameters significantly differed between age groups, and that gender also influenced certain pressure metrics. Notably, the percentage of load on the forefoot increased with advancing age, while the percentage of load on the rearfoot decreased.

The study found that women had significantly higher average and maximum pressures in the right foot compared to men. This may be attributed to anatomical and biomechanical differences in female foot structure. Similarly, the significantly larger contact area observed in men may be associated with the generally larger foot size in males, as reported in previous studies [11]. Other studies have also highlighted that men tend to have a wider plantar contact area and differing load distribution patterns. Although women exhibited higher average and maximum pressures in the right foot, consistent with the literature, no significant gender-based difference was found in forefoot load percentage [12], suggesting that gender differences manifest more prominently in pressure parameters rather than in overall load distribution. This could be due to structural and anatomical variations between the sexes.

Comparative data across age groups demonstrated a strong influence of aging on foot pressure distribution. Specifically, older individuals (Group 2) exhibited higher forefoot load percentages, lower rearfoot load percentages, and a higher forefoot/rearfoot maximum pressure ratio. These findings imply that postural adaptations may shift body weight more anteriorly with age. Previous literature supports this, indicating that in older adults, anterior weight shift serves as a postural stabilization mechanism, resulting in increased forefoot loading and altered weight transfer strategies [13,14]. However, no significant age-related differences were found in maximum pressure or contact area. This suggests that while age affects general load distribution, variations in pressure and contact area may be more dependent on individual differences.

Pedobarographic analysis provides objective information on foot function, gait, postural stability, and lower extremity biomechanics, thereby guiding diagnosis, rehabilitation protocols, and treatment monitoring [15]. When analyzing by gender, no significant differences were observed in forefoot and rearfoot load percentages. This implies that gender may have a limited effect on load distribution during the aging process.

These findings emphasize the impact of aging on foot pressure distribution and highlight the importance of considering age-related biomechanical changes in the maintenance of postural stability. The increased forefoot loading in older adults may have implications for balance mechanisms and fall risk. Accordingly, it is essential to develop appropriate clinical assessment and rehabilitation strategies to address postural changes and reduce fall risk in the elderly. Our findings support the need for further research to more comprehensively investigate the biomechanical consequences of aging on foot loading patterns.

This study has several limitations. Since static pedobarography was used, pressure changes during gait were not assessed. The absence of dynamic analysis limits our understanding of load distribution during the gait cycle. Postural compensation mechanisms were not evaluated; only data from static standing positions were analyzed. Additionally, factors such as participants' daily physical activity levels, footwear habits, and foot care practices were not controlled for, which may have influenced foot pressure distribution and, consequently, the interpretation of results.

Conclusion

In conclusion, this study evaluated the effects of age and gender on foot pressure distribution using static pedobarographic analysis. Our results demonstrate that foot pressure distribution differs across age groups.

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Patient Informed Consent
Written informed consent was obtained from all participants in the study.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
The study received ethical approval from the Biruni University Clinical Research Ethics Committee Ethics Committee (Approval Number:2015-KAEK-80-23-46) (Approval Date: 22.12.2023).

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