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Effect of Weightlifting Shoes on Bilateral Plantar Pressure Distribution During 50 kg Loaded Full Squats in Internationally Competing Weightlifters

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Abstract

The aim of this study is to systematically examine the plantar pressure distribution under constant load in weightlifters wearing weightlifting shoes and to identify possible asymmetries between the right and left feet. The study's research group consisted of 17 male weightlifters who participated in international competitions. Foot pressure measurements were performed using a Sensor Medica (Italy) baropodometric measuring device. A total of 25 pairs of variables (right-left foot) related to peak plantar pressure, mean pressure, contact area, center of pressure, and regional load distribution were analyzed during squat exercises performed by participants with a constant load of 50 kg. The findings showed a statistically significant difference between the right and left foot in 5 out of 25 pairs of variables ($p < .05$). Most of the significant differences were concentrated in pressure and load parameters (medial and lateral mean pressure of the hindfoot, overall maximum and mean pressure, load on the 2nd and 3rd metatarsal heads), and in these variables, the left foot showed significantly higher values with moderate to large effect sizes ($d = 0.72$-1.31) compared to the right foot. In contrast, small to moderate differences were found in contact surface variables (total contact surface, toes, 4th-5th metatarsal heads, hindfoot lateral contact percentage) in favor of the right foot ($d = -0.55$ to -0.97). No significant differences were observed between the two feet in the remaining 32 variables (footprint length, COP indices, Fick angle, forefoot/heel loads, etc.). In conclusion, it was found that the plantar pressure distribution in weightlifters is largely symmetrical, but a significant pressure/load dominance in favor of the left foot, particularly in the rear foot region, and conversely, a tendency for a larger contact surface in the right foot. This pattern is consistent with discussions in the literature regarding the dominant/non-dominant extremity difference and bilateral load symmetry specific to weightlifting. The findings indicate that foot-specific support strategies, rather than identical ones for both feet, should be considered in the design of weightlifting shoes and insoles.

Keywords: Weightlifting, Weightlifting Shoes, Foot Pressure Distribution, Center of Force (COF), Biomechanics.

Özet

Uluslararası Düzeyde Yarışan Haltercilerde 50 Kg Ağırlıkla Tam Squat Sırasında Halter Ayakkabılarının İki Taraflı Plantar Basınç Dağılımı Üzerindeki Etkisi

Bu çalışmanın amacı, halter ayakkabısı giyen haltercilerde, sabit yük altında ayak taban basınç dağılımını sistematik olarak incelemek ve sağ-sol ayak arasındaki olası asimetrileri belirlemektir. Çalışmanın araştırma grubunu uluslararası düzeyde yarışmalara katılan 17 erkek halterci oluşturmaktadır. Ayak tabanı basınç ölçümleri Sensör Medica (İtalya) baropodometrik ölçüm cihazı ile gerçekleştirilmiştir. Katılımcıların, 50 kg sabit yük ile gerçekleştirdiği squat hareketi sırasında tepe plantar basınç, ortalama basınç, temas alanı, basınç merkezi ve bölgesel yük dağılımına ilişkin toplam 25 değişken çifti (sağ-sol ayak) analiz edilmiştir. Bulgular, 25 değişken çiftinden 5 tanesinde sağ ve sol ayak arasında istatistiksel olarak anlamlı fark olduğunu göstermiştir ($p < .05$). Anlamlı farkların büyük kısmı basınç ve yük parametrelerinde (arka ayak medial ve lateral ortalama basınç, genel maksimum ve ortalama basınç, 2-3. metatars başları yükü) yoğunlaşmış ve bu değişkenlerde sol ayakta sağ ayağa göre orta-büyük etki büyüklüğüyle (d = 0.72-1.31) belirgin biçimde daha yüksek değerler saptanmıştır. Buna karşılık, temas yüzeyi değişkenlerinde (toplam temas yüzeyi, parmaklar, 4-5. metatars başları, arka ayak lateral temas yüzdesi) sağ ayak lehine küçük-orta düzeyde farklar bulunmuştur (d = -0.55 ile -0.97 arası). Kalan 32 değişkende (ayak izi uzunluğu, COP indeksleri, Fick açısı, ön ayak/topuk yükleri vb.) iki ayak arasında anlamlı bir fark gözlenmemiştir. Sonuç olarak, haltercilerde ayak taban basınç dağılımının büyük ölçüde simetrik olduğu, ancak özellikle arka ayak bölgesinde sol ayak lehine belirgin bir basınç/yük üstünlüğü, buna karşılık sağ ayakta daha geniş bir temas yüzeyi eğiliminin bulunduğu tespit edilmiştir. Bu örüntü, literatürdeki dominant/non-dominant ekstremite farkı ve halter sporuna özgü bilateral yük simetrisi tartışmalarıyla uyumludur. Bulgular, halter ayakkabısı ve tabanlık tasarımında her iki ayak için özdeş değil, ayağa özgü destek stratejilerinin değerlendirilmesi gerektiğine işaret etmektedir.

Anahtar Kelimeler: Halter, Halter Ayakkabıları, Ayak Tabanı Basınç Dağılımı, Kuvvet Merkezi (COF), Biyomekanik.

INTRODUCTION

Weightlifting is one of the oldest and most technically demanding competitive sports in the world (1,2). An Olympic sport, weightlifting is a sport where male and female athletes compete individually and as a team in specific age and weight categories (3). It requires explosive strength, balance, and technical precision, and performance largely depends on the correct distribution of the load on the single point of contact with the ground (the sole of the foot) (4). This sport requires athletes to lift maximum weights above their heads using two standard movements (snatch and clean and jerk). Unlike many other sports, it is a symmetrical sport, except for the second period of the clean and jerk, considering the dominant hand and foot usage (5). During each phase of the lifting movement (start, pull, squat, and lift), the projection of the body's center of gravity onto the sole of the foot constantly changes, creating varying pressure loads in different anatomical regions of the foot. Therefore, evaluating plantar pressure distribution is an important area of research for understanding both performance and injury risk.

Pedobarography, a method that allows for the static and dynamic measurement of plantar pressure, reveals the distribution of plantar pressure according to anatomical regions through color-coded maps and numerical data. This enables the early identification of areas exposed to high pressure, thus guiding shoe and insole design (6). It has been repeatedly shown through studies in various sports that plantar pressure distribution exhibits a sport-specific pattern (7,8,9). It is believed that the plantar pressure distribution in weightlifters differs from that of other athletes and sedentary individuals. Therefore, evaluating this distribution is important to identify areas subjected to excessive pressure and to prevent potential injuries by designing appropriate footwear/insoles (10). Furthermore, this evaluation is considered a crucial criterion for improving performance, comfort, and foot health in athletes (11). In weightlifting, the foot and shoe, which serve as the primary interface between the athlete and the ground, play a fundamental role in the force transmission process. Any asymmetry, imbalance, or misalignment in the sole of the foot can propagate upwards along the biokinetic chain, altering the joint mechanics in the ankle, knee, hip, and lumbar spine (12). Another important variable affecting plantar pressure distribution is the type of shoe used. It has been reported that the rigid midsole and elevated heel structure, characteristic of weightlifting shoes, increase the amount of plantar flexion in the ankle, altering the muscle activation pattern during squats and leading to greater engagement of the plantar flexor muscles (13). The special heel structure reduces the need for excessive ankle dorsiflexion during the squat phase, providing a more upright trunk position and reducing the load on the spine and hip joints (14), and it has been shown that a 25 mm heel height can be a preferable option for anteroposterior stability. It has also been reported that motor neuron activation in the midfoot region is significantly reduced in squats performed with extremely high heels such as 40 mm and 70 mm compared to shorter heels (15). These findings demonstrate that optimizing design parameters such as heel height and sole rigidity is crucial in terms of pressure distribution on the sole of the foot and potential injury risks (16).

For weightlifters, understanding the relationship between weightlifting shoes, lifted weights, and pressure distribution is crucial not only for improving and understanding performance, but also for developing technical skills that can enhance the athlete's performance at different stages of training and competition. The findings will also provide a better understanding of the load distribution and area on the right and left feet during weightlifting. The study is expected to contribute to the determination of shoe design and selection criteria and provide applicable data for performance specialists working with this group of athletes. In line with these expectations, the study aims to determine the changes in maximal pressure and pressure areas on the right and left feet during weightlifting and to evaluate these changes in terms of athlete performance, shoe sole, and insole.

METHOD

Research Model: This study is a cross-sectional, observational, and paired-measurement laboratory study aiming to compare the right and left sole pressure distributions during a squat exercise performed under a constant load of 50 kg by weightlifters wearing weightlifting shoes and included in the sample group (17).

Research Group: The study included 17 male volunteer weightlifters with international competition experience, no history of injury, and who regularly trained in weightlifting. Demographic and anthropometric characteristics such as age, height, body weight, and training age were recorded for the participants. Inclusion criteria included actively participating in weightlifting, having no current injury or pain, abstaining from alcoholic and caffeinated beverages, and being able to lift at full capacity on the measurement day. Participants were also instructed to avoid strenuous physical activity the day before. Individuals with any orthopedic problems, neurological disorders, or foot deformities (pes planus, pes cavus, etc.) were excluded from the study. The study was approved by the Ethics Committee of the Faculty of Architecture and Design, Selçuk University (decision no: 03/06 dated 30.04.2026).

Data Collection Tool: Foot pressure measurements of the weightlifters were performed using a Sensor Medica (Italy, 2023) baropodometric measuring device, which consists of 400 sensors placed in the insoles of their shoes. Prior to the measurements, the device was calibrated according to the manufacturer's calibration protocol. All participants wore Nike 4 Romaleos weightlifting shoes in their correct size during the measurements.

Procedure: The study was conducted in May 2026 at the Konya Youth and Sports Provincial Directorate weightlifting hall. After height and body weight measurements were taken, participants performed a standard warm-up protocol suitable for their training routine for 15 minutes before baropodometric measurements. After warming up, each participant performed a squat exercise with a fixed weight of 50 kg. Two valid trials were recorded for each participant with the same load, and the best trial was selected for analysis. Measurements were recorded synchronously during the defined phases of the lift (starting position, pulling phase, entry into the squat, standing up), and a total of 25 pairs of variables (right-left foot) related to peak plantar pressure, mean pressure, contact area, center of pressure, and regional load distribution were analyzed. All measurements were performed on the same day, under the same surface conditions, and under the supervision of 4 researchers. Participants were instructed to wear sportswear (shorts, t-shirt, weightlifting shoes, etc.) during the measurements.




Figure 1. Lifting **Figure 2**. Squat **Figure 3.** Pressure Analysis **Figure 4**. Sensor Medica

Evaluation of Data Analysis: Whether the data met the assumption of normal distribution was evaluated using skewness and kurtosis values and Q-Q plots. Since the data were found to conform to a normal distribution, descriptive statistics are presented as mean ± standard deviation ($\bar{x} \pm SS$). The Paired Samples t-test was used to compare the pressure differences between the right and left feet. In all analyses, the statistical significance level was accepted as $p < 0.05$, and the analyses were performed using SPSS 27 software.

FINDINGS

Foot Pressure Analysis of Weightlifters During 50 kg Full Squat

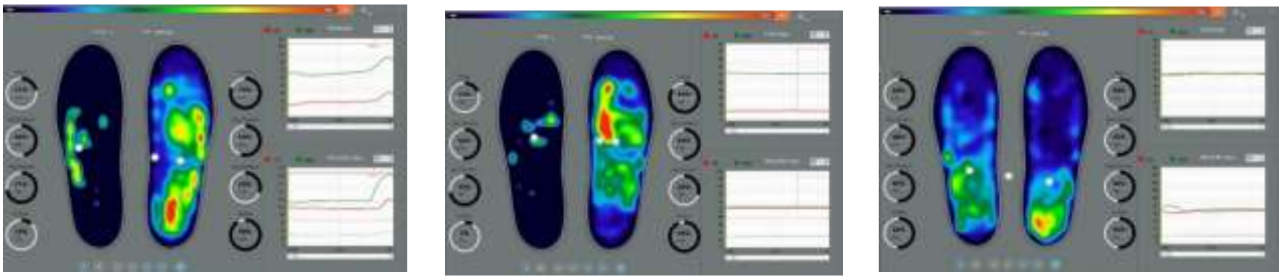

Figure 5,6,7. Participants' Foot Pressure Analysis Chart Samples

Table 1. Demographic and Anthropometric Characteristics of Weightlifters (n = 17)

Variable	n	M	SD	Min	Max	Skewness
Age (Years)	17	15.94	2.08	13	19	0.29
Body Weight (kg)	17	74.12	19.63	52	130	1.18
Height (cm)	17	171.53	6.67	160	186	-0.04
BMI (kg/m²)	17	25.51	4.74	18.0	37.6	1.12
Shoe Size	17	41.76	1.48	39	46	1.54

M= Arithmetic mean; SD = Standard deviation; Min = Minimum; Max = Maximum; BMI = Body Mass Index.

The mean age of the 17 weightlifters participating in the study was determined to be 15.94 ± 2.08 years (13–19 years). The mean body weight of the participants was 74.12 ± 19.63 kg (52–130 kg), the mean height was 171.53 ± 6.67 cm (160–186 cm), and the mean body mass index (BMI) was 25.51 ± 4.74 kg/m². The mean shoe size was 41.76 ± 1.48, with participants having shoe sizes ranging from 39 to 46. The observed positive skewness values for body weight and BMI variables (1.18 and 1.12, respectively) indicate that a few athletes in the sample had significantly higher values for these variables compared to others.

Table 2. Comparison of Left and Right Foot Pressure Parameters During 50 kg Full Squat Using Paired Samples t-Test (n = 17)

	Left Foot		Right Foot		Paired t-test Results			
Variable	**Left M**	**Left SD**	**Right M**	**Right SD**	**t**	**df**	**p**	**Cohen's d**
Maximum Pressure (gr/cm²)	2414.88	945.49	1517.53	281.29	4.283	16	.001*	1.04
Mean Pressure (gr/cm²)	882.53	413.68	438.65	63.28	4.373	16	< .001*	1.06
RF Medial Surface Area (cm²)	108.35	15.75	106.88	11.44	0.486	16	.634	0.12
RF Lateral Surface Area (cm²)	86.59	11.78	95.71	10.11	-3.985	16	.001*	-0.97
RF Medial Load (%)	54.47	5.46	53.47	4.80	0.702	16	.493	0.17
RF Lateral Load (%)	45.53	5.46	46.53	4.80	-0.702	16	.493	-0.17
Contact Area (cm²)	195.47	19.74	202.65	20.04	-2.253	16	.039*	-0.55
Contact Time (ms)	10402.94	4913.51	12158.82	2331.54	-1.535	16	.144	-0.37
Delta CoF (mm)	107.59	40.16	114.35	33.98	-0.810	16	.430	-0.20
CoF Global Index (%)	39.47	15.28	40.82	12.91	-0.476	16	.641	-0.12
Initial CoF Index (%)	29.94	10.60	28.00	9.14	0.845	16	.410	0.20
Final CoF Index (%)	30.59	8.92	31.18	8.24	-0.287	16	.778	-0.07
Fick Angle (°)	0.29	2.62	1.35	2.45	-1.394	16	.182	-0.34
Footprint Length (mm)	247.94	87.09	253.82	88.87	-0.190	16	.852	-0.05

M = Mean; SD = Standard Deviation; t = Paired-samples t-test statistic; df = Degrees of Freedom; p = Significance Level; d = Cohen's d Effect Size.. *p < .05.

When the paired sample t-test results were examined, the maximum pressure values were found to be statistically significantly higher in the left foot (M = 2414.88 ± 945.49 kg/cm²) compared to the right foot (M = 1517.53 ± 281.29 kg/cm²), $t(16) = 4.283$, $p = .001$, $d = 1.04$. A large effect size ($d \geq 0.80$) indicated that the left foot functioned as the dominant load-bearing foot under the 50 kg load. The mean pressure values also showed an asymmetry in the same direction; the left foot (M = 882.53 ± 413.68 kg/cm²) was statistically significantly higher than the right foot (M = 438.65 ± 63.28 kg/cm²), $t(16) = 4.373$, $p < .001$, $d = 1.06$ (large effect). Consistent left predominance in both pressure parameters confirms that this asymmetry pattern has a systematic feature. In terms of RF lateral surface area, the right foot (M = 95.71 ± 10.11 cm²) was found to be statistically significantly larger than the left foot (M = 86.59 ± 11.78 cm²), $t(16) = -3.985$, $p = .001$, $d = -0.97$ (large effect). This large lateral contact area observed in the right foot can be considered as a compensatory adaptation mechanism to mechanically balance the high-pressure load on the left side. A significant difference was also found between the two feet in terms of total contact surface; the contact surface of the right foot (M = 202.65 ± 20.04 cm²) was statistically larger than that of the left foot (M = 195.47 ± 19.74 cm²), $t(16) = -2.253$, $p = .039$, $d = -0.55$ (moderate effect). Despite the contact surface being wider in the right foot, the pressure values being much higher in the left foot indicates a difference in load distribution efficiency between the two feet. No significant differences were found in terms of RF medial surface area, RF load values, contact time, CoF indices, Fick angle, and footprint length (all $p > .05$).

Table 3. Comparison of Regional Load Distribution on Left and Right Legs During 50 kg Full Squat Using Paired Samples t-Test (n = 17)

	Left Foot		Right Foot		Paired t-test Results			
Variable	**Left M**	**Left SD**	**Right M**	**Right SD**	**t**	**df**	**p**	**Cohen's d**
FOREFOOT								
Forefoot Total Load (%)	68.25	18.34	72.70	6.19	-1.013	16	.326	-0.25
Hallux Load (%)	9.37	2.88	10.05	3.65	-0.793	16	.439	-0.19
Fingers Load (%)	5.14	3.00	5.83	2.56	-0.955	16	.354	-0.23
First Metatarsal Head Load (%)	8.35	2.75	8.34	2.84	0.005	16	.996	0.00
Second–Third Metatarsal Head Load (%)	13.84	3.60	10.76	2.85	3.378	16	.004*	0.82
REARFOOT								
Rearfoot Total Load (%)	27.71	6.75	27.13	6.29	0.367	16	.718	0.09
Medial Heel Load (%)	16.19	4.60	15.92	4.33	0.175	16	.863	0.04
MEDIAL / LATERAL								
Medial Arch Load (%)	12.08	4.35	13.02	4.34	-1.276	16	.220	-0.31
Lateral Arch Load (%)	12.89	3.10	12.38	2.54	0.778	16	.448	0.19
Total Medial Load (%)	53.65	5.76	52.97	4.83	0.447	16	.661	0.11

Table 3. Comparison of Regional Load Distribution on Left and Right Legs During 50 kg Full Squat Using Paired Samples t-Test (n = 17)

	Left Foot		Right Foot		Paired t-test Results			
Variable	**Left M**	**Left SD**	**Right M**	**Right SD**	**t**	**df**	**p**	**Cohen's d**
Total Lateral Load (%)	45.98	5.83	47.03	4.83	-0.676	16	.509	-0.16

M = Mean; SD = Standard Deviation; t = Paired t-test statistic; df = Degrees of Freedom; p = Significance Level; d = Cohen's d effect size. p < .05.

In regional load distribution comparisons, only the percentage of load on the Metatarsal Head II-III showed a statistically significant difference between the left and right feet. The Metatarsal II-III load ratio in the left foot (M = 13.84 ± 3.60 %) was found to be significantly higher compared to the right foot (M = 10.76 ± 2.85 %), t(16) = 3.378, p = .004, d = 0.82 (large effect). This finding confirms the existence of an asymmetric loading pattern concentrated on the central metatarsal heads in the anterior region of the left foot during the full squat movement. The metatarsal region II-III constitutes a critical point for forefoot weight transfer during squatting. Left-right weight asymmetry in this region should be considered a significant risk factor for the development of pathologies such as stress fractures, metatarsalgia, and plantar fasciitis, especially in cases of chronic overloading. No statistically significant differences were found between the two feet in terms of total forefoot load, hallux load, toe load and metatarsal head load, all t(16) values remained at p > .05. In the hindfoot region, no statistically significant differences were observed in the comparison of total hindfoot load and medial heel load; and in the medial-lateral region, no statistically significant differences were observed in the comparison of medial arch load, lateral arch load, total medial load and total lateral load (all p > .05). These findings indicate that asymmetric loading is mainly localized in the forefoot-midfoot region and that the balance of hindfoot and overall medial-lateral load is maintained symmetrically between the two sides.

Table 4. Statistically Significant Variables – Paired t-test and Effect Size Summary (n = 17)

Variable	**t**	**df**	**p**	**Cohen's d**	**Effect Size**
Maximum Pressure (gr/cm²)	**4.283**	**16**	**.001***	**1.04**	**Big**
Average Pressure (gr/cm²)	**4.373**	**16**	**< .001***	**1.06**	**Big**
RF Surface Lateral (cm²)	**-3.985**	**16**	**.001***	**-0.97**	**Big**
Contact Surface Area (cm²)	**-2.253**	**16**	**.039***	**-0.55**	**Middle**
Metatarsal Head II-III Load (%)	**3.378**	**16**	**.004***	**0.82**	**Big**

All comparisons were performed using a paired t-test. Cohen's d classification: 0.20–0.49 = Small; 0.50–0.79 = Medium; ≥ 0.80 = Large (Cohen, 1988). *p < .05.

Paired-sample t-tests revealed statistically significant left-right asymmetry in five variables. All significant variables showed moderate or large Cohen's d effect sizes. Maximum pressure (d = 1.04) and mean pressure (d = 1.06) had the highest effect sizes, with the left foot showing a clear advantage in both parameters. RF lateral surface area (d = -0.97) and Metatarsal Head II-III load percentage (d = 0.82) showed large effect sizes, while total contact surface area showed a moderate effect size (d = -0.55). Negative d values reflect right foot dominance, while positive d values reflect left foot dominance. This table summarizes how a left-dominant pressure strategy under a 50 kg load is shaped by a compensatory contact surface expansion in the right foot, and that load asymmetry in the forefoot metatarsal region requires clinical attention. From a clinical perspective, the left-dominant pressure asymmetry identified in this group of young weightlifters (average age 15.94 years) provides strong evidence for training interventions aimed at technical correction and bilateral symmetry. Restructuring squat technique with a focus on left-foot weight management and implementing proprioceptive training programs are recommended for maintaining long-term musculoskeletal health and reducing the risk of injury.

DISCUSSION AND CONCLUSION

In this study, during squat exercises performed with a constant load of 50 kg by weightlifters wearing weightlifting shoes, statistically significant differences were found between the right and left feet in 5 out of 25 pairs of variables; in the remaining 20 variables, a symmetrical distribution of both feet was determined. The lack of statistically significant differences (p > .05) in the majority of the 20 pairs of variables analyzed (footprint length, COP indices, Fick angle, and load percentages) indicates that the basic anthropometric structure and general postural balance are maintained between the two extremities. However, the significant differences observed in the remaining 5 variables ($p < .05$) reveal that the asymmetry is not random but clustered along two fundamental biomechanical axes: a clear superiority in favor of the left foot is observed in pressure and load parameters, while there is an expansion in favor of the right foot in contact surface and area parameters. Nevertheless, it is stated that weightlifting performance is related more to relative strength (load lifted per unit of body weight) than absolute strength (18). This indicates that the lifted load represents a different relative load depending on the athlete's body weight, and therefore, the load on the sole of the foot can vary between individuals.

The findings largely coincide with existing literature showing that plantar pressure in weightlifters generally follows a symmetrical pattern, but significant asymmetries may exist in certain anatomical regions (particularly the hindfoot). In an assessment performed during gait in elite male weightlifters, while a generally similar pressure and force distribution pattern was found between the right and left feet, significant differences were detected in peak pressure in the medial midfoot region and maximum force parameters in the ninth zone (10); this is consistent with the "mostly symmetrical but with regionally significant differences" result observed in the study. Similarly, in a study comparing the foot characteristics of elite male weightlifters to a healthy control group, it was found that the center of pressure (CoP) was symmetrically distributed in both feet, but when the plantar load distribution was examined at the sub-region level, the medial metatarsal region of the left foot carried significantly higher load (19); this finding confirms that although weightlifting requires a bilateral and synchronized movement pattern, left-right differences can occur in specific foot regions.

The significantly higher hindfoot pressure values in the left foot observed in the study may be related to dominant/non-dominant extremity differentiation. In female Olympic-style weightlifters, the highest average plantar pressure was consistently recorded in the hindfoot region of the non-dominant extremity in all participants; it has been suggested that this may be related to functional shortening of the superficial dorsal line, imbalances in muscle tension on the plantar surface, or hamstring contractures (12). Assuming that the vast majority of participants are right-handed/foot-dominant, the finding of high hindfoot pressure in the left foot (potentially the non-dominant extremity) is consistent with the literature and supports the idea that the hindfoot region of the non-dominant extremity may be particularly prone to point loading in weightlifting. This appears to be one of the most important criteria to consider, especially in the development of weightlifting shoes.

Interpreting the findings in the context of weightlifting shoes is also important. Regarding the effect of heel height on lower extremity symmetry during back squats, it is known that bilateral lower extremity asymmetry is a common finding during the back squat movement, but raising the heel does not significantly alter the degree of this asymmetry (20). This finding explains the significant pressure asymmetries that emerged even with weightlifting shoes in the study; heel height alone should not be considered a factor that equalizes the load distribution between the two feet. Furthermore, it is known that lower extremity biomechanics in weightlifting movements differ at the joint level depending on the load; it has been shown that varying the load in the range of 65-85% 1TM during the pulling phase significantly affects angular velocity, torque, and power generation in the ankle, knee, and hip joints (21). This finding suggests that the study's limitation lies in being conducted only at a constant load of 50 kg; the asymmetry pattern may change quantitatively and qualitatively at different load percentages (e.g., 65%, 75%, 85% 1TM). Furthermore, considering that athletes have different techniques in both snatch and clean and jerk, it is thought that the production of weightlifting shoes should be evaluated taking into account the different model and design features of both. Even if the athletes' foot analysis measurements are taken while performing a 50 kg full squat, evaluating the weightlifters according to their snatch and clean and jerk with maximum weight during the competition is more important for the development of weightlifting shoes.

In conclusion, the study findings reveal that plantar pressure distribution is largely symmetrical in weightlifters wearing weightlifting shoes, but significant differences with moderate to large effect sizes favoring the left foot are found, particularly in the medial/lateral regions of the hindfoot and in maximum and mean pressure parameters. This situation indicates that the asymmetrical distribution of foot pressure during weightlifting causes the weight to be loaded onto the left side of the body. This can negatively affect the athlete's athletic performance. This finding is consistent with discussions in the literature regarding the difference between dominant and non-dominant extremities and bilateral load symmetry specific to weightlifting (22, 23, 24, 25). Furthermore, these results indicate that foot-specific (asymmetrical) support strategies, rather than identical ones for both feet, should be considered in weightlifting shoe and insole design; additional pressure-distributing supports in the hindfoot region of the non-dominant extremity may be beneficial. It can be suggested that weightlifters using their own rigid insoles may improve their performance.

REFERENCES

1. Storey, A., & Smith, H. K. (2012). Unique Aspects of Competitive Weightlifting: Performance, Training and Physiology. Sports Medicine, 42(9), 769–790. https://doi.org/10.1007/BF03262294
2. Steele, J., Keogh, J., & Loenneke, J. P. (2022). Editorial: Understanding & Improving Performance in Strength Sports. Frontiers in Sports and Active Living, 4, 807941. https://doi.org/10.3389/fspor.2022.807941
3. Erdağı, K., Tüfekçi, O., Yeşeri, M., Yüksel, M. F., Turgut, N., & Eroğlu, B. E. (2020). A study on the determination of handgrip strength of Olympic style weightlifting athletes. Physical Education of Students, *24*(3), 141-148.
4. Soriano, M. A., Suchomel, T. J., & Comfort, P. (2019). Weightlifting Overhead Pressing Derivatives: A Review of the Literature. Sports Medicine, 49(6), 867–885. https://doi.org/10.1007/s40279-019-01096-8
5. Urso, A. (2014). Weightlifting: Sport for All Sports. Ed. Calzetti-Mariucci. Olympic World Library.
6. Cerrahoğlu, A. B. L., & Ulusoy, A. (2020). Ayak ve Ayak Bileği Sorunlarında Ayak Taban Basıncı Değerlendirmesi (Pedobarografik Olarak). A. B. L. Cerrahoğlu (Ed.), Ayak ve Ayak Bileği Ağrıları Tanı ve Tedavisi (1. Edition, 44–47). Ankara: Türkiye
7. Açıkgöz, Y., & Cengizel, E. (2023). The Relationship between Plantar Pressure Distribution and Balance in Adolescent Taekwondo Athletes. Gazi Journal of Physical Education and Sport Sciences, 28(2), 160–166. https://doi.org/10.53434/gbesbd.1217210
8. Chow, T.-H., Chen, Y.-S., & Hsu, C.-C. (2021). Relationships between Plantar Pressure Distribution and Rearfoot Alignment in the Taiwanese College Athletes with Plantar Fasciopathy during Static Standing and Walking. International Journal of Environmental Research and Public Health, 18(24), 1-18. 10.3390/ijerph182412942
9. Usgu, S., Yakut, Y. & Çınar, M. A. (2020). The Comparison of Achilles Tendon Viscoelastic Properties in Elite Runners and Soccer Players. Turkish Journal of Sports Medicine, 55(4), 276–283. https://doi.org/10.5152/tjsm.2020.185
10. Pirani, H. & Azizi, M. (2020). Comparison of peak pressure, maximum force, contact area, and contact time between the right and left foot in elite weightlifters. Journal of Kermanshah University of Medical Sciences, 24(1), 1-8 e96967. https://doi.org/10.5812/jkums.96967
11. Uzun, A, Aydos, L., Kaya, M., Pekel, H. A. & Kanatlı, U. (2018). "Effect of Soccer Foot Pressure on Pressure Distributions," Journal of Education and Training Studies, 6 (6), 70–76.
12. Hawrylak A. & Gronowska H. (2020). Plantar Pressure Distribution in Female Olympic-Style Weightlifters. Int J Environ Res Public Health. 17(8), 1-8, 2669. doi: 10.3390/ijerph17082669. PMID: 32295025; PMCID: PMC7215572.
13. Mohammadi, M. M.. & Nourani, A. (2025). Testing the Effects of Footwear on Biomechanics of Human Body: A Review. Heliyon, 11(4), e42870. https://doi.org/10.1016/j.heliyon.2025.e42870
14. Sato, K., Fortenbaugh, D. & Hydock, D. S. (2012). Kinematic changes using weightlifting shoes on barbell back squat. Journal of Strength and Conditioning Research, 26(1), 28–33. https://doi.org/10.1519/JSC.0b013e318218dd64
15. Duan, L., Fekete, G., Ugbolue, U. C., & Zhou, H. (2025). The Influence of Different Heel Heights on Squatting Stability: A Systematic Review and Network Meta-Analysis. Applied Sciences, 15(5), 1-14. https://doi.org/10.3390/app15052471
16. Melvin, J. M., Price, C., Preece, S., Nester, C, & Howard, D. (2019). An Investigation into the Effects of, and Interaction Between, Heel Height and Shoe Upper Stiffness on Plantar Pressure and Comfort. Footwear Science, 11(1), 25–34. https://doi.org/10.1080/19424280.2018.1555862
17. Karasar, N. (2019). Bilimsel Araştırma Yöntemi: Kavramlar, İlkeler, Teknikler Ankara: Nobel Akademik Yayıncılık
18. Aydos, L., Uzun, A., Özel, R., & Esen, E. (2012). Haltercilerde Fiziksel Yapı ve Rölatif Kuvvet İlişkisinin Araştırılması. Selçuk Üniversitesi Beden Eğitimi ve Spor Bilim Dergisi, 14(1), 31–36.
19. Chow, T.-H., Chen, Y.-S., Chou, H.-T., Chang, C.-C., & Lin, M.-H. (2025). Biomechanical Adaptations in Foot Characteristics Among Elite Male Weightlifters: A Cross-Sectional Comparative Study. Medical Science Monitor, 31, e950416. https://doi.org/10.12659/MSM.950416
20. Sayers, M. G. L., Hosseini Nasab, S. H., Bachem, C., Taylor, W. R., List, R. & Lorenzetti, S. (2020). The Effect of Increasing Heel Height on Lower Limb Symmetry During the Back Squat in Trained and Novice Lifters. BMC Sports Science, Medicine and Rehabilitation, 12, 42. https://doi.org/10.1186/s13102-020-00191-y
21. Kipp, K., Harris, C. & Sabick, M. B. (2011). Lower Extremity Biomechanics During Weightlifting Exercise Vary Across Joint and Load. Journal of Strength and Conditioning Research, 25(5), 1229–1234. https://doi.org/10.1519/JSC.0b013e3181da780b
22. Lake, J. P., Lauder, M. A. & Smith, N. A. (2010). The Effect That Side Dominance Has on Barbell Power Symmetry During the Hang Power Clean. Journal of Strength and Conditioning Research, 24(11), 3180–3185. https://doi.org/10.1519/JSC.0b013e3181da77ca

23. Lake, J. P., Lauder, M. A. & Smith, N. A. (2011). Does Side Dominance Affect the Symmetry of Barbell End Kinematics During Lower-Body Resistance Exercise? Journal of Strength and Conditioning Research, 25(3), 872–878. https://doi.org/10.1519/JSC.0b013e3181cc2397
24. Sato, K. & Heise, G. D. (2012). Influence of Weight Distribution Asymmetry on the Biomechanics of a Barbell Back Squat. Journal of Strength and Conditioning Research, 26(2), 342–349. https://doi.org/10.1519/JSC.0b013e318220e0a3
25. Lee, S., Levine, N. & Kim, J. (2026). An Exploratory Study in Relationship Between Biomechanical Bilateral Asymmetry and Power Output During the Power Clean. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology (advance online publication). https://doi.org/10.1177/17479541261415600