Original Article Clinics in Orthopedic Surgery 2022;14:281-288 • https://doi.org/10.4055/cios20260

Change of In-Shoe Plantar Pressure According to Types of Shoes (Flat Shoes, Running Shoes, and High Heels)

Yun Jae Cho, MD, Dong-Woo Lee, MD, Hyuck Soo Shin, MD*,#, Yoon Bin Hwang, MD*, Dong Oh Lee, MD*, Dae-Yoo Kim, MD*,#, Dong Yeon Lee, MD*

Department of Orthopedic Surgery, Han-il General Hospital, Seoul,
**Department of Orthopedic Surgery, Seoul National University Hospital, Seoul, Korea*

Background: The type of footwear is one of several factors that affect foot pressure. Despite its usefulness in identifying pathology and preventing and treating foot-related diseases, the type of shoes has been investigated and compared in only a few studies. This study aimed to investigate differences in plantar pressure, induced by flat, running, and high-heeled shoes in healthy, young women.

Methods: A total of 27 healthy women (27 feet) with a mean age of 21.5 ± 2.03 years were included in this study. Based on demographic data, radiologic measurements, clinical scores, temporal gait parameters, and kinematic parameters of gait, we confirmed the participants had normal feet. Then, pedobarographic data were measured by dividing each foot into seven regions to compare the three types of shoes. Peak plantar pressure and pressure-time integral were calculated using the Pedar-X system. The one-way analysis of variance and the Kruskal-Wallis test with Mann Whitney *U*-test were used for statistical analyses.

Results: Regarding the 7 regions of the foot, flat shoes resulted in a significantly higher pressure than running shoes in the hallux and lesser toes and the highest pressure in the metatarsal head (MTH) 3–5 and the hindfoot. In contrast, in the MTH 1 and MTH 2 regions, the high-heeled shoes had the highest measured pressure, followed by the flat shoes. Lastly, there was no high pressure in running shoes in any region except for the midfoot compared to the other shoes.

Conclusions: It can be inferred from our findings that flat and high-heeled shoes can generate a considerable burden on specific parts of the foot, which will aid in choosing appropriate shoes. Also, wearing running shoes places less burden on the overall foot.

Keywords: *Foot, Pressure, Pedobarography, Shoes*

The condition of many foot-related diseases can be changed in response to plantar pressure (PP) and shocks, and different types of shoes have been developed to protect the feet over several decades. Recently, as footwear types have been diversified, many studies have reported that wearing appropriate shoes may be a clinically therapeutic tool, beyond merely protecting the foot and preventing foot-related diseases.1) Therefore, the measurement of PP caused by footwear can be crucial for evaluating the burden applied on the feet and predicting disease occurrence and progression.

PP measurements have traditionally been made to evaluate pressure between the barefoot and the floor.2) Recent studies have used pedobarography to analyze PP under different footwear conditions, especially dynamic rather than static pedobarography.3) PP measurements between the foot and a shoe provide a way to better under-

---

Received October 25, 2020; Revised December 21, 2021;
Accepted December 27, 2021
Correspondence to: Dae-Yoo Kim, MD
Department of Orthopedic Surgery, Seoul National University Hospital, Seoul, Korea
#Current affiliation: Hyuck Soo Shin: CM Hospital, Seoul, Korea
Dae-Yoo Kim: Department of Orthopedic Surgery, Busan Paik Hospital, Inje University College of Medicine, 75 Bokji-ro, Busanjin-gu, Busan 47392, Korea
Tel: +82-51-890-6257, Fax: +82-51-892-6619, E-mail: kdyhoho@hanmail.net

Clinics in Orthopedic Surgery • pISSN 2005-291X eISSN 2005-4408

stand the effects of shoe design modifications on foot mechanics. Hence, pedobarography is thought to potentially influence both shoe designs and the clinical management of foot-related diseases.

Several studies have reported on changes in foot pressure by shoe type using pedobarography. Mandato and Nester4) reported the effect of increased PP on the heel and Carl et al.5) reported the effect of different shoe designs on the PP of the forefoot. Chapman et al.6) suggested that wearing appropriate rocker shoes may offer an optimal balance for offloading different regions of the forefoot. Wegener et al.7) also suggested that neutral-cushioned running shoes were effective in improving PP patterns. Although these studies have reported noticeable results, bony deformities in radiologic measurements or clinical scores reflecting foot symptoms and gait patterns of subjects were not examined. In addition, most studies focused on feet with pathologic problems, specific groups such as athletes, or therapeutic shoes.

Therefore, this study aimed to identify differences in foot PP by shoe type (flat, running, and high-heeled) to provide guidelines for selecting appropriate types of shoes for ordinary people. We hypothesized that running shoes would be most appropriate in asymptomatic people by redistributing and reducing PP evenly. Furthermore, we used radiologic examination, clinical scores, and gait analysis to determine whether our study participants had normal feet.

METHODS

Participants

We conducted this study in compliance with the principles of the Declaration of Helsinki. The consent forms were obtained and protocol of this prospective comparative research was reviewed and approved by the Institutional Review Board of Seoul National University Hospital (IRB No. H-1711-023-897). A total of 32 young female volunteers were recruited in the study.

Inclusion criteria were as follows: (1) no history of lower extremity fracture or surgery; (2) no subjective symptoms such as pain or discomfort during gait; (3) no history of lower-extremity injuries in the past 6 months; (4) no observed radiographic features of deformity on simple radiographs of the hip, knee, ankle, or foot; and (5) normal function of the foot and ankle (Foot and Ankle Outcome Score [FAOS] > 450 [of 500] and American Orthopaedic Foot & Ankle Society [AOFAS] ankle-hindfoot score > 90 [of 100]). During a preceding experiment, two volunteers were excluded because they had smaller foot sizes than the shoes we prepared for. Three volunteers showing abnormal angles (both hallux valgus and pes planus) in plain radiographs were excluded (see Radiological and Clinical Scores section). As a result, 27 healthy women aged 18–25 years were tested and one side was selected randomly for statistical analyses. The mean height was 162.26 cm and mean weight was 55.18 kg. The mean volunteer age was 21.56 years. Shoe size was 239.81 mm.

Study Design

We investigated demographic data, radiologic measurements, clinical scores, temporal gait parameters, and kinematic parameters of gait to confirm that the participants' foot function was normal. The participants were selected according to the inclusion criteria and their gait data were found to be within the normal range (± 2 standard deviation [SD]) when compared to the data of a reference group (young healthy female group described in our previous study).8) The reference group consisted of 50 women (50 feet) tested only on the right side with a mean age of 27.3 ± 4.0 years and their radiologic features and clinical scores were within the normal range. Then, pedobarographic data were measured by dividing the foot into designated regions to compare the three types of shoes.

Gait Data in Experimental Procedures

The experimental procedures were the same as those in our previous study.9) Briefly, the participants were asked to perform easy walking for 5 minutes to warm up. A single operator with 17 years of experience (YBH) placed reflective markers from the Helen Hayes marker set. The participants were asked to walk at their usual speed along a 9-m track. Gait data were collected using 12 cameras at a height of 2 m with an optical motion capture system (Motion Analysis Co., Santa Rosa, CA, USA) at a sample rate of 120 Hz. Eight cameras were set at each octant position (45° intervals). Eva Real-Time software (EVaRT, Motion Analysis Co.) and Microsoft Excel 2010 were used for real-time motion capture, post-processing, and tracking of the marker data.

Temporal and spatial gait parameters were obtained. The authors analyzed the cadence (cm), speed (cm/sec), stride length (cm), and step width (cm) (Table 1). For the analysis of the kinematic data, 3 representative strides from 5 separate trials were selected and the mean values were used. To assess normal gait pattern, range of motion was analyzed at the pelvis, hip, knee, and ankle during the gait cycle. And we divided the entire gait cycle into 100 time points with 1% interval and collected intersegmental angles at each time point. To assess the repeatability of

Table 1. Demographic Data and Temporal Gait Parameter of Participants

Demographic data	Mean ± SD
Age (yr)	21.56 ± 1.69
Weight (kg)	55.18 ± 7.27
Height (cm)	162.26 ± 3.66
Shoe size (mm)	239.81 ± 4.49
Cadence (step/min)	116.6 ± 2.5
Speed (cm/sec)	125.6 ± 3.4
Stride length (cm)	128.3 ± 2.7
Step width (cm)	10.5 ± 4.1

SD: standard deviation.

the gait pattern in our study, we calculated coefficients of multiple correlation (CMC) to confirm the degree of correspondence with the reference group.

Radiological and Clinical Scores

Radiological features included to confirm the degree of pes planus or hallux valgus were as follows: lateral talus-first metatarsal angle (Meary's angle), 1–2 intermetatarsal (IMT) angles, and first metatarsophalangeal (MTP) angle.

All participants were surveyed using the FAOS and AOFAS ankle-hindfoot questionnaire scores for subjective symptoms during gait. We calculated the mean score of the 5 FAOS subscales in our subject group and used only the ankle–hindfoot platform in the AOFAS score.

Pedobarographic Measurements

The pedobarographic measurements were collected using the Pedar-X in-shoe pressure measuring system (Novel Co., Munich, Germany), which is 15 × 10 × 4 cm and weighs 400 g. The insoles are 22–49 in European shoe size, in 3 widths, and 1.9 mm thick and have 99 sensors embedded with a pressure range of 30–1,200 kPa. The foot pressures were recorded at a rate of 50 Hz. The Pedar-X system's reliability and validity have been proven in several studies.[10)]

Three trials were collected: practice, trial 1, and trial 2. The participants wore the standardized shoes and were asked to walk for 5 minutes during the practice period. The participants were asked to look ahead and walk at a comfortable and speed-controlled pace for at least 30 steps for all data acquisition processes.

To ensure the data's validity, at least 30 steps were left after editing, and only the right side was used to exclude the effect of the dominant foot.[11)] We modified Bergstra's masks for pressure parameters consisting of the hallux, toes 2–5, metatarsal head (MTH) 1, MTH 2, MTH 3–5, midfoot, and hindfoot[12)] (Fig. 1). Peak PP (PPP) and pressure-time integral (PTI) were assessed from each region using Pedar-X software Pedar online. PPP and PTI are used in the clinical field to evaluate pain and disease.[13)]

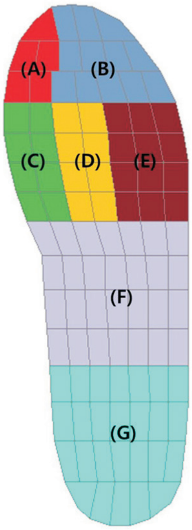


Fig. 1. Plantar areas selected for pressure analyses (modified 7 mask region). (A) Hallux. (B) Second–fifth toe. (C) First metatarsal head (MTH 1). (D) Second MTH (MTH 2). (E) Third–fifth MTH (MTH 3–5). (F) Midfoot. (G) Hindfoot.

Shoe Type

Three types of shoes–running, flat, and high-heeled–were examined in this study (Fig. 2). The running shoes are constructed with foam in the rearfoot, midfoot, and forefoot regions and an inflexible outsole. The flat shoes had a heel height of 1 cm and less foam than the running shoes in the rearfoot, midfoot, and forefoot regions. The high-heeled shoes had narrow toe boxes, low vamps, thin heel widths, and a heel height of approximately 7 cm.

Statistical Analysis

The Shapiro-Wilk and Kolmogorov-Smirnov tests were performed to confirm the normality analysis. Analysis of differences among the three types of shoes was conducted using one-way analysis of variance including Tukey's method test to evaluate pairwise differences as a post hoc test. To compare the gait analysis to that of the reference group, Pearson correlation was performed. A $p < 0.05$ was set as a statistical significance. All statistical analyses were performed using IBM SPSS ver. 23.0 (IBM Corp., Armonk, NY, USA).

Fig. 2. Standardized shoes: (A) flat shoes, (B) running shoes, (C) high heels.

RESULTS

Clinical Score

Clinical AOFAS (mean ± standard deviation [SD], 98.8 ± 2.8) and FAOS (mean ± SD, 484.8 ± 21.9) scores were nearly perfect.

Radiographic Measurements

Radiologic measurements showed that the mean angle and SD in the participants were within the normal range of Meary's angle (mean angle, –2.30° to –1.87°; SD, 2.69), 1–2 IMT angle (mean angle, + 7.06° to + 8.02°; SD, 1.51), and first MTP angle (mean angle, + 9.64° to + 9.69°; SD, 3.25).

Temporal Gait Parameters

The mean cadence was 116.6 step/min and the mean speed was 125.6 cm/sec. The mean stride length was 128.3 cm and mean step width was 10.5 cm (Table 1). Temporal and spatial gait parameters did not differ significantly between groups for any of the values.

Kinematic Parameters

The gait patterns generally seemed consistent. The range of motion of the pelvis, hip, knee, and ankle from the volunteer group showed a narrow range of variability and the ranges were within the values of the reference group during the gait cycle (Fig. 3). The mean intra-session CMC (± SD) was 0.94 (± 0.08). The intra-session CMC of all parameters were interpreted as having excellent or very good correspondence with the reference group.[14)]

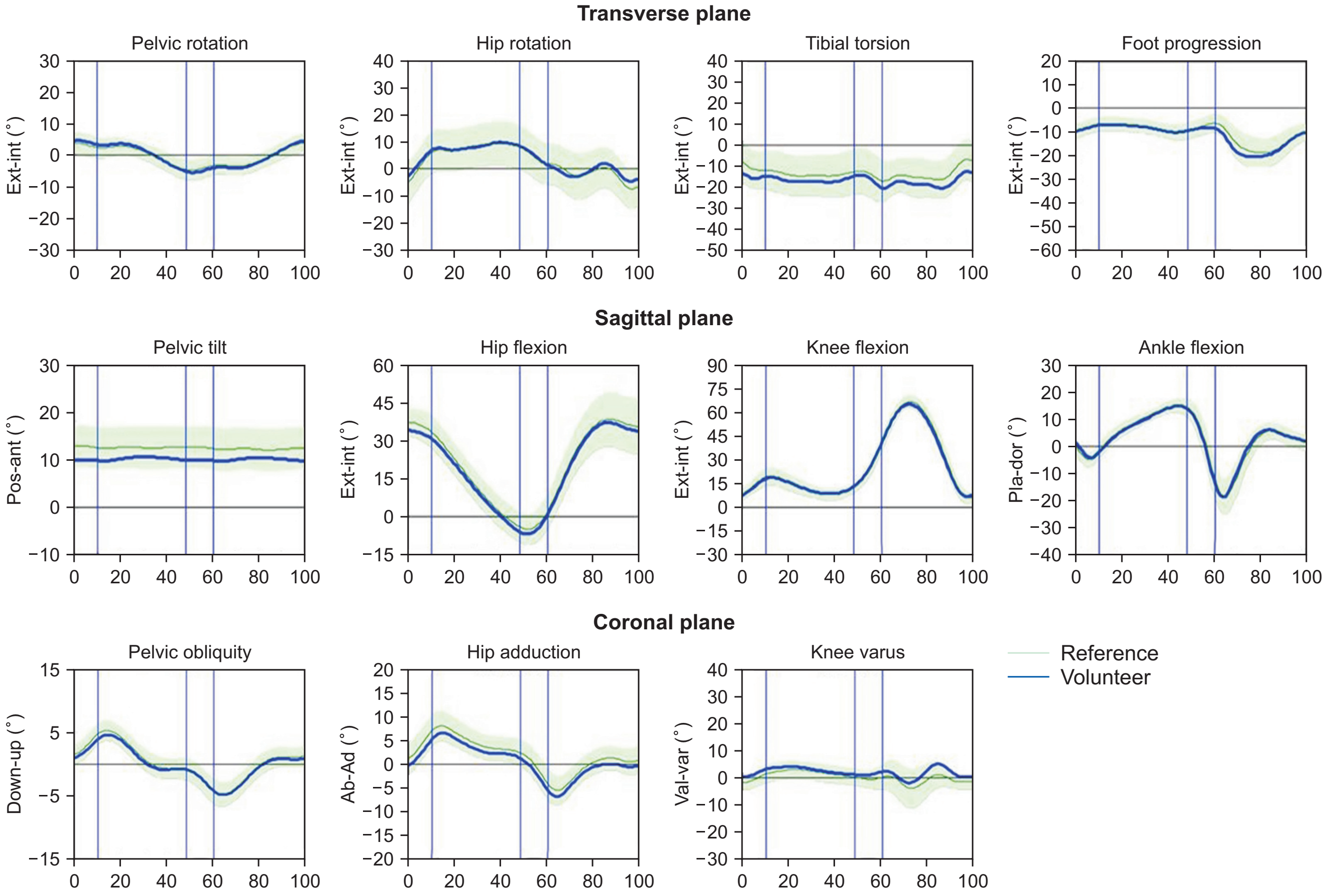
Pressure Measurements

Table 2 shows the differences in PP scores among the shoe types by foot regions. Interpretation of the data was done only when both PPP and PTI showed statistically significant differences. Under hallux and toes 2–5, the flat shoes showed higher PPP and PTI than did the running shoes. In the hindfoot, the flat shoes had higher PPP and PTI than the other shoes. In MTH 1 and MTH 2, the high-heeled shoes showed the highest PPP and PTI, followed by the flat shoes and then running shoes. The running shoes had higher PPP and PTI than the other shoes in the midfoot and the lowest PPP and PTI in MTH 3–5 (Fig. 4).

DISCUSSION

We investigated the fundamental loading on the plantar side of the foot with each shoe type in healthy people in daily life. The participants were selected as those with normal feet based on radiological examinations and clinical scores. In addition, the gait analysis of the participants was compared with the normal range of gait analysis of the 50 young and healthy women included in our previous study.[8)] After confirming that the participants' feet were normal and free of any problems, we studied the differences in PP among flat, running, and high-heeled shoes.

This results showed that running shoes had lower PTI and PPP in all regions than the other shoes except the midfoot region, where the highest PTI and PPP were observed. Given that running shoes have insoles, they support the arch of the foot and increase the overall contact



Transverse plane

Pelvic rotation, Hip rotation, Tibial torsion, Foot progression

Sagittal plane

Pelvic tilt, Hip flexion, Knee flexion, Ankle flexion

Coronal plane

Pelvic obliquity, Hip adduction, Knee varus

Fig. 3. Comparison of the gait patterns between the volunteer group and the reference group in three planes. The mean coefficient of multiple correlation was 0.94 (± 0.08), demonstrating high correlations between the groups. Ext-int: external rotation-internal rotation, Pos-ant: posterior-anterior, Pla-dor: plantarflexion-dorsiflexion, Ab-Ad: abduction-adduction, Val-var: valgus-varus.

area including the midfoot. As a result, running shoes can disperse PP and reduce both PPP and PTI in the overall region. Burns et al.15) also showed that a reduction in PTI by 26% with custom-made foot orthoses was associated with a reduction in foot pain by 74% with an elevated PP. Similar studies have demonstrated that pressure-reducing qualities of neutral-cushioned running shoes may also be an effective treatment modality for runners with foot pain or injury.16) Consistent with previous studies, we demonstrated that walking in running shoes reduces the burden on the foot by distributing the pressure through cushioning and resolves foot problems related to pressure such as diabetic foot ulcer or Morton's neuroma.

In contrast, flat shoes had both high PPP and PTI in all regions except the midfoot. In particular, the hallux region was the highest, followed by the heel region. Because flat shoes have no insole construction that absorbs or reduces the overall pressure compared to running shoes, the impact during heel-strike affects the hindfoot region more strongly. These results are similar to the barefoot condition in that the hindfoot, second MTH, and hallux are known to have the highest PP.17) In addition, considering that PPP and PTI increased in the heel region, higher pressure occurred for a much longer time in the heel region of the flat shoe than in the running shoe. This mechanism could be explained by related hindfoot diseases such as plantar fasciitis and fat pad atrophy. Flat shoes for patients suffering from plantar fasciitis may not be appropriate because they may cause overloading and excessive stretching of plantar aponeurosis.18) Thus, the heel cup insert with viscoelastic properties effectively reduced the pressure of the heel region and augmented the capability of energy absorption the body already processed in terms of natural heel pad, especially in flat shoes.19)

Meanwhile, flat shoes had higher PPP and PTI in the hallux, lesser toes, and MTH regions compared to the running shoe. In normal gait cycle, repetitive and larger biomechanical stresses usually occur on the big toe and MTH to produce propulsive force. Mueller et al.20) reported that PPP in patients suffering from diabetes was signifi-

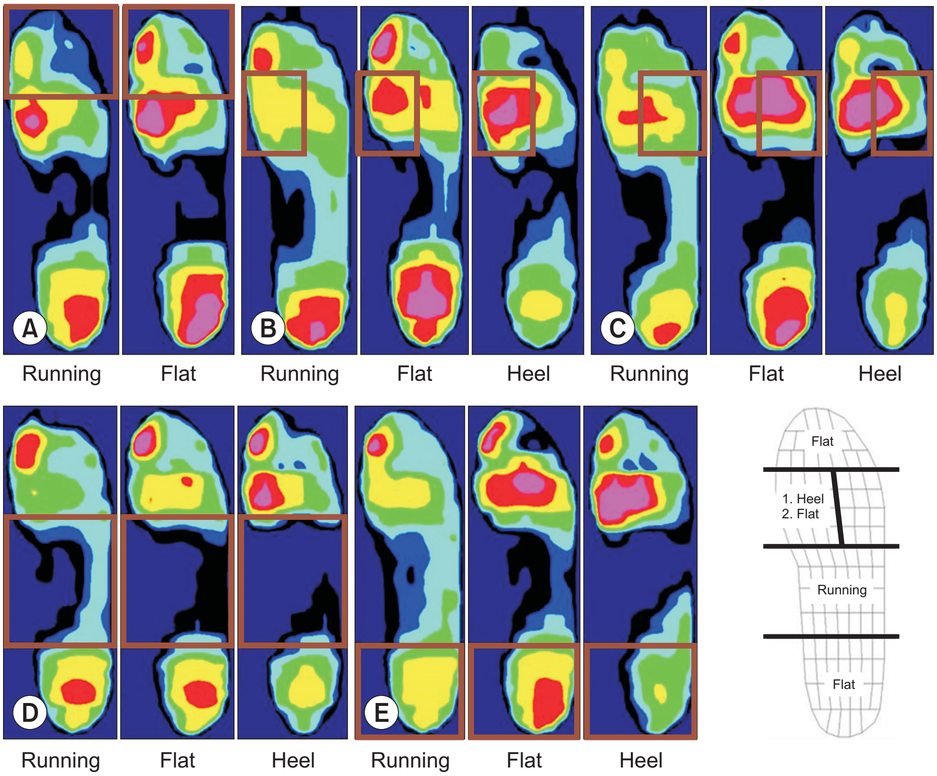


Fig. 4. Peak plantar pressure (PPP) image pattern of pedobarographic measurements. (A) Under hallux and toes 2–5, flat shoes showed higher PPP than running shoes. (B) Under first metatarsal head (MTH 1) and MTH 2, high-heeled shoes showed the highest PPP. (C, D) Running shoes showed the lowest PPP under MTH 3–5 and highest PPP in midfoot. (E) In the hindfoot, flat shoes had higher PPP. Pink: over 300 kPa, red: 220–300 kPa, yellow: 150–220 kPa, green: 100–150 kPa, sky blue: 60–100 kPa, blue: 40–60 kPa, black: 15–40 kPa, white: under 15 kPa.

cantly higher in the forefoot, where most skin defects occur, compared to those in the hindfoot when walking barefoot. Caselli et al.[21)] showed that forefoot PPP was about 2.3 times higher than rearfoot PPP in people with diabetes and severe neuropathy was 1.3 times higher in a mild neuropathic group. Hence, considering the high pressure in the forefoot region, such as in flat shoes, these patterns can be a significant risk factor in diabetic patients suffering from ulcer-like diseases.

Because of the narrow toe box and high height of the heel region of high-heeled shoes, some people who wear high heels are vulnerable to foot disorders such as calluses, hallux valgus, and even sprains.[22)] Many studies demonstrated that PPP in the forefoot increases significantly with increasing heel height.[4)] In addition, as expected, high-heeled shoes showed the highest PPP and PTI in MTH 1–2.

The forward slope caused by the heel component of the hindfoot and center of the pressure position was thought to cause anterior and medial movement from the foot centerline, and the pressure was concentrated in the forefoot area, such as MTH 1–2.[23)] Luximon et al.[24)] also showed that the small hill base surface (HBS) produced a higher PP in the toe region, but the large HBS increased the PP over the forefoot, midfoot, and hindfoot. In addition, PTI in MTH 1–2 and MTH 3–5 was the highest with a significant difference. Pain-related high pressure in MTH is typically associated with standing activity and may be linked to wearing heels or tight shoes that compress the toe box.[25)] These can be risk factors for Morton's neuroma in middle-aged women who frequently wear high-heeled shoes.[26)]

One of the limitations of this study is that the three types of shoes used in our study may not be representative models of each type of shoes because the design, contour, and insole may vary even among the same type of shoes according to brands. In addition, the socks worn by the participants were not controlled, which could have resulted in poor prognosis of the PP. Also, the investigators and participants were not blinded to the shoe insole conditions, which varied in contour. Finally, we should have assessed the reliability of the radiographic and pedobarographic measurements with different independent raters.

In summary, the high-heeled shoes showed high pressure in MTH 1–2, while the flat shoes showed high pressure in the hallux and hindfoot. In addition, running shoes showed less pressure in all of the regions during walking, which indicates that wearing running shoes places less burden on the foot. In conclusion, this study demonstrated that flat and high-heeled shoes can generate considerable burdens on specific parts of the foot. The understanding of the PP according to shoe type can be helpful in the selection of appropriate shoes for the people who

Table 2. Mean Difference in Pressure between Shoe Types

Variable	Run–flat	*p*-value*,†	Run–high	*p*-value	Flat–high	*p*-value
Peak plantar pressure (kPa)						
Hallux	–113.383	< 0.001	26.657	0.560	140.040	0*
Toes 2–5	–50.611	< 0.001	8.781	0.411	59.392	0*
MTH 1	–61.645	0.014	–131.210	< 0.001*,†	–69.565	0.005*,†
MTH 2	–85.077	< 0.001	–139.691	< 0.001*,†	–54.614	0.034*,†
MTH 3–5	–86.235	< 0.001	–58.580	< 0.001*,†	27.654	0.171
Midfoot	25.034	< 0.001	20.580	< 0.001*,†	–4.454	0.533
Hindfoot	–67.901	< 0.001	77.228	< 0.001*	145.130	< 0.001*,†
Pressure-time integral (kPa × sec)						
Hallux	–31.840	< 0.001	–22.770	< 0.001*	9.070	0.270
Toes 2–5	–20.106	< 0.001	–13.617	< 0.001*	6.489	0.687
MTH 1	–14.887	< 0.001	–50.774	< 0.001*,†	–35.886	< 0.001*,†
MTH 2	–16.302	< 0.001	–52.403	< 0.001*,†	–36.101	< 0.001*,†
MTH 3–5	–18.146	< 0.001	–33.039	< 0.001*,†	–14.893	0.004*
Midfoot	10.572	< 0.001	11.955	< 0.001*,†	1.382	0.381
Hindfoot	–18.818	< 0.001	–1.960	0.494	16.858	< 0.001*,†

MTH: metatarsal head, PPP: peak plantar pressure, PTI: pressure–time integral.
*Statistically significant. †Statistically significant in both PPP and PTI (interpretable).

have clinical symptoms related to PP of the foot.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ORCID

Yun Jae Cho	https://orcid.org/0000-0003-3030-5035
Dong-Woo Lee	https://orcid.org/0000-0003-4142-7759
Hyuck Soo Shin	https://orcid.org/0000-0001-9789-4167
Yoon Bin Hwang	https://orcid.org/0000-0002-1985-1804
Dong Oh Lee	https://orcid.org/0000-0001-7646-9778
Dae-Yoo Kim	https://orcid.org/0000-0002-6273-7337
Dong Yeon Lee	https://orcid.org/0000-0001-8233-6285

REFERENCES

1. Bucki M, Luboz V, Perrier A, et al. Clinical workflow for personalized foot pressure ulcer prevention. Med Eng Phys. 2016;38(9):845-53.
2. Lord M. Foot pressure measurement: a review of methodology. J Biomed Eng. 1981;3(2):91-9.
3. Skopljak A, Muftic M, Sukalo A, Masic I, Zunic L. Pedobarography in diagnosis and clinical application. Acta Inform Med. 2014;22(6):374-8.
4. Mandato MG, Nester E. The effects of increasing heel height on forefoot peak pressure. J Am Podiatr Med Assoc. 1999;89(2):75-80.
5. Carl HD, Pfander D, Swoboda B. Assessment of plantar pressure in forefoot relief shoes of different designs. Foot Ankle Int. 2006;27(2):117-20.
6. Chapman JD, Preece S, Braunstein B, et al. Effect of rocker shoe design features on forefoot plantar pressures in people with and without diabetes. Clin Biomech (Bristol, Avon).

2013;28(6):679-85.

7. Wegener C, Burns J, Penkala S. Effect of neutral-cushioned running shoes on plantar pressure loading and comfort in athletes with cavus feet: a crossover randomized controlled trial. Am J Sports Med. 2008;36(11):2139-46.
8. Lee DY, Seo SG, Kim EJ, Kim SJ, Lee KM, Choi IH. Intersegmental motions of the foot in healthy adults: Gender difference. J Orthop Sci. 2016;21(6):804-9.
9. Seo SG, Lee DY, Moon HJ, et al. Repeatability of a multisegment foot model with a 15-marker set in healthy adults. J Foot Ankle Res. 2014;7:24.
10. Putti AB, Arnold GP, Cochrane L, Abboud RJ. The Pedar in-shoe system: repeatability and normal pressure values. Gait Posture. 2007;25(3):401-5.
11. Melvin JM, Preece S, Nester CJ, Howard D. An investigation into plantar pressure measurement protocols for footwear research. Gait Posture. 2014;40(4):682-7.
12. Bergstra SA, Kluitenberg B, Dekker R, et al. Running with a minimalist shoe increases plantar pressure in the forefoot region of healthy female runners. J Sci Med Sport. 2015; 18(4):463-8.
13. Rao S, Douglas Gross K, et al. Are pressure time integral and cumulative plantar stress related to first metatarsophalangeal joint pain?: results from a community-based study. Arthritis Care Res (Hoboken). 2016;68(9):1232-8.
14. Garofalo P, Cutti AG, Filippi MV, et al. Inter-operator reliability and prediction bands of a novel protocol to measure the coordinated movements of shoulder-girdle and humerus in clinical settings. Med Biol Eng Comput. 2009;47(5):475-86.
15. Burns J, Crosbie J, Ouvrier R, Hunt A. Effective orthotic therapy for the painful cavus foot: a randomized controlled trial. J Am Podiatr Med Assoc. 2006;96(3):205-11.
16. Burns J, Crosbie J, Hunt A, Ouvrier R. The effect of pes cavus on foot pain and plantar pressure. Clin Biomech (Bristol, Avon). 2005;20(9):877-82.
17. Rodgers MM, Cavanagh PR. Pressure distribution in Morton's foot structure. Med Sci Sports Exerc. 1989;21(1):23-8.
18. Wearing SC, Smeathers JE, Urry SR. The effect of plantar fasciitis on vertical foot-ground reaction force. Clin Orthop Relat Res. 2003;(409):175-85.
19. Jorgensen U, Ekstrand J. Significance of heel pad confinement for the shock absorption at heel strike. Int J Sports Med. 1988;9(6):468-73.
20. Mueller MJ, Zou D, Bohnert KL, Tuttle LJ, Sinacore DR. Plantar stresses on the neuropathic foot during barefoot walking. Phys Ther. 2008;88(11):1375-84.
21. Caselli A, Pham H, Giurini JM, Armstrong DG, Veves A. The forefoot-to-rearfoot plantar pressure ratio is increased in severe diabetic neuropathy and can predict foot ulceration. Diabetes Care. 2002;25(6):1066-71.
22. Menz HB, Morris ME. Footwear characteristics and foot problems in older people. Gerontology. 2005;51(5):346-51.
23. Han TR, Paik NJ, Im MS. Quantification of the path of center of pressure (COP) using an F-scan in-shoe transducer. Gait Posture. 1999;10(3):248-54.
24. Luximon Y, Cong Y, Luximon A, Zhang M. Effects of heel base size, walking speed, and slope angle on center of pressure trajectory and plantar pressure when wearing high-heeled shoes. Hum Mov Sci. 2015;41:307-19.
25. Davis F. Therapeutic massage provides pain relief to a client with Morton's neuroma: a case report. Int J Ther Massage Bodywork. 2012;5(2):12-9.
26. Summers A. Diagnosis and treatment of Morton's neuroma. Emerg Nurse. 2010;18(5):16-7.