

## Article

# Effectiveness of Shock-Absorbing Insole for High-Heeled Shoes on Gait: Randomized Controlled Trials

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**Abstract:** This study was carried out to identify the influence of a shock-absorbing insole, developed by the author for use with high-heeled shoes, on walking. The research design included single-blind randomized parallel groups; namely, a group of 26 participants who wore the shock-absorbing insoles and another group of 26 participants who did not wear the insoles, both carried out walking while wearing 7 cm high-heels. During walking, plantar pressure analysis (via in-shoe plantar pressure measurements), surface electrode electromyography (surface EMG), gait analysis, subjective comfort evaluation, and functional movement (functional mobility) analysis were carried out. In order to compare the two groups, statistical verification (paired t-test) was performed. Wearing the shock-absorbing insole with the high-heeled shoes improved posture stability during walking, as well as increasing the walking speed. In addition, the heel pressure, the pressure of the front foot at the inner side, and the shock ability were decreased. For these reasons, the wearers reported higher comfort. Changes in the muscle activities of the tibialis anterior muscle (TA) and the gastrocnemius muscle (GA) heightened the stability of the ankle joints. Overall, the proposed shock-absorbing insole for use with high-heeled shoes improved the postural stability when walking, as well as improving the distribution of pressure on the soles. A decrease in the diverse side-effects of wearing high-heeled shoes can thus be expected.

**Keywords:** high-heeled shoes; surface electromyography (EMG); plantar pressure; randomized controlled trial; shock-absorbing insole



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## 1. Introduction

Despite extensive warnings from public health organizations and international medical societies regarding the hazards of high-heeled (HH) shoes, the population wearing them in everyday life remains high [1]. According to the change of the center of mass of the body, not only do HH shoes change the body alignment, they also have harmful influences on walking and the function of the lower extremities [2]. High external knee joint loads have been related to anterior cruciate ligament injury [3], lower extremity over-use injury [4], knee pain [5], and osteoarthritis of the knee [6].

In order to absorb the increased vertical shock inflicted when walking while wearing HH shoes, not only are biomechanical adaptations of the spine needed, but the kinematic and kinetic characteristics are also altered [7]. Therefore, an effective method for reducing the adverse effects of HH shoes should be provided. Insoles, for either decreasing the impact force related to HH shoes or for absorption, may be an important solution in this context. An insole that absorbs impact force can improve the sole pressure distribution while walking, and can effectively prevent leg injury [8]. Insoles that are inserted to improve the stability of the feet and the shoes, as well as the sense of wear, have diverse material and physical characteristics [9].

Regarding previous research—including studies on the influence of the use of in-soles on the forces between the foot and the ground and reducing the maximum impact force—the effect of the insole regarding the ground reaction force and the sole pressure has been reported [1,7,10]. To date, research on the effect of insoles, in terms of reducing the impact

force while walking, and studies comparing the subjective comfort of consumers through the analysis of exercise dynamic data in actual circumstances of use have been inadequate.

Regarding the human body as a connected chain [11], a compensation action appears after wearing HH shoes. As a result, in this research, a method to offset the negative influence of wearing HH shoes is developed. Regarding a shock-absorbent insole for use with HH shoes developed by the researcher, in order to determine its influence on walking, the alleviation of shock absorption, along with the results of in-shoe plantar pressure, a surface EMG, a gait analysis, subjective comfort, and functional mobility measurements, are compared and analyzed.

## 2. Materials and Methods

The research protocol and the written consent were examined and approved by the Institutional Review Board at Semyung University, case number SMU-2021-04-003-01. With adult women aged from 20–50 as the subjects, the purpose and method of this research was explained prior to the study. The women who consented, in writing, to participation were selected. All of the experiments were carried out according to the Helsinki Declaration of the World Medical Association. From August 2021 until October 2021, 56 participants were recruited. The criteria for selecting the subjects of the research were as follows:

1. Healthy adult women;
2. Persons who consented to the purpose and the method of this research, which were explained to them beforehand;
3. Persons who had not suffered from a musculoskeletal injury to the lower extremities within the past year;
4. Persons who did not have an orthopedic disability or pain in the lower Extremities;
5. Persons whose buttocks, knees, and ankle joint range of motion (ROM) were in the normal range;
6. Persons who satisfied height in the range of 155–175 cm and WHO Standard Normal BMI Index of 18.5–24.9.

The height (cm) and weight (kg) of the subjects were measured using an automatic height measuring machine GL-150 (G-tech International, Uijeongbu, Korea), in an upright position and taking off their shoes. Body mass index (BMI) was calculated by measuring height (m) and weight (kg) and dividing the weight by the square of the height ( $\text{kg}/\text{m}^2$ ) [12]. Shoe size and International Physical Activity Questionnaires (IPAQ) were collected through a self-administered questionnaire.

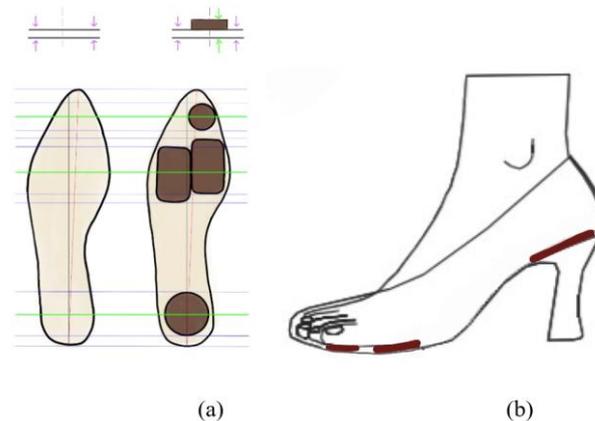
### 2.1. Sample Size

Regarding the size of the research sample, by utilizing the G\*Power 3.1 Program, as a result of calculating the effect size ( $d = 0.80$ ), significance ( $\alpha = 0.05$ ), and examination ability ( $1 - \beta = 0.80$ ), the number of subjects was calculated as 52 persons in total, with 26 persons per each group. Taking into account the in-the-middle failure rate of the subjects of the research being 10%, although 28 persons were selected for the experiment group and 28 persons were selected for the control group (a total of 56 participants) [13,14], as there were four participants whose data were inadequate, the final number of subjects was 26 in the experimental group and 26 in the control group (for a total of 52 participants).

### 2.2. The Information Regarding the Shock-Absorbing Insole for Use with HH Shoes

In order to prepare a plan for reducing the pressure concentrated on a specific part when wearing HH shoes, the researcher developed a shock-absorbing insole for use with HH shoes, which protects the body by reducing foot fatigue and dispersing the weight to the entire foot, based on the results of an analysis of the distribution of the plantar pressure and a biomechanical analysis. Regarding the shock-absorbing insoles for use with HH shoes, referring to the results of a previous experiment, in which a leading foot pressure analyzer was used, after the insoles were directly inserted into the shoes [15], the feet were protected from impact force and the feeling of the wearer was heightened. In

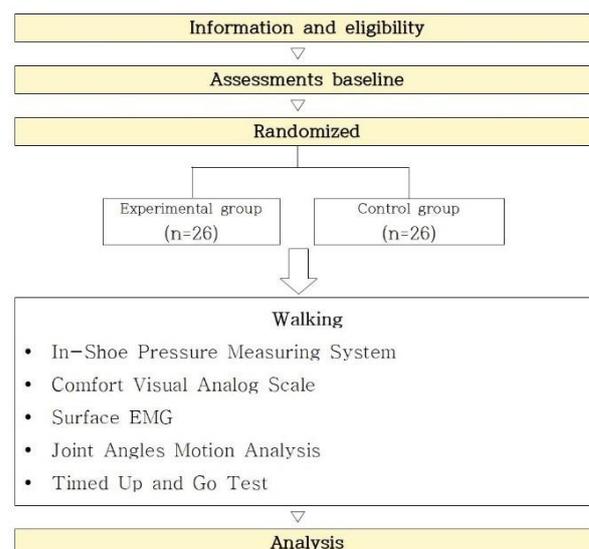
particular, the hindfoot felt more cushioned by the insole. By increasing the entire thickness and by considering factors such as shock absorption, pressure dispersion, permeability, anti-bacterial characteristics, weight, stability, etc., the insole was developed. The special feature of the design of the insole product is the presence of cushions at four parts of the foot: The hallux, the medial forefoot, the lateral forefoot, and the heel. In addition, there is an adhesive sticker, making it is a product that can replace the standard cushion for shock relief, according to the shape of the foot, including a marking line for cutting to different sizes (Figure 1).



**Figure 1.** (a) The shock-absorbing insole for use with HH shoes; and (b) an illustration of the insertion of an insole in a high-heel shoe, where the height of the heel is 7 cm.

### 2.3. Study Design

Through randomization (specifically, a randomization table), the subjects were allocated to a group wearing the insoles (the experimental group) or a group that did not wear the insoles (the control group). When participants were assigned to a group randomly, they were not informed whether they were in the experimental group or control group. A flowchart explaining the experimental protocol is provided in Figure 2.



**Figure 2.** Protocol for a single-blind, randomized, parallel-group study.

### 2.4. Experimental Procedure

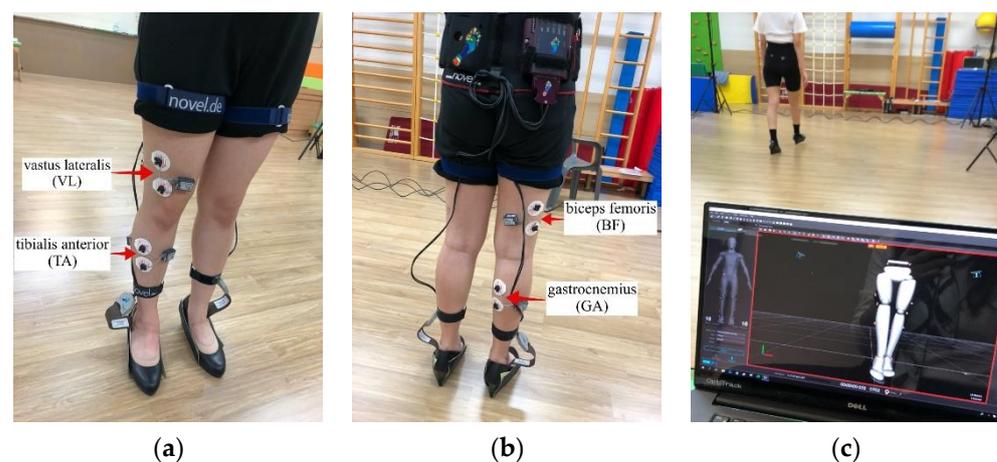
In order to exclude environmental influences, all measurements were carried out in a measurement room where there was no noise. Regarding the area of the contact surface of the floor with the heels of the 7 cm high-heel shoes, both were around 1 cm<sup>2</sup>. To fit the sizes

of the feet of all subjects, the same model product was applied. An EMG electrode was attached before measuring the plantar foot pressure. The activities of the anterior of the dominant side leg, the tibialis anterior (TA), the gastrocnemius (GA), the vastus lateralis (VL), and the biceps femoris (BF) that appeared while the subject walked were all measured. The measurement device and the variables used in this research are detailed in Table 1.

**Table 1.** The experimental equipment used to determine the influence of the designed insole on walking, as well as the shock absorption effect.

	Equipment Model (Company)	Variables	Unit
In-Shoe Pressure Measuring System	Pedar-X System (Novel GmbH, Germany)	Peak pressure (PP) Contact area (CA)	kPa cm <sup>2</sup>
Comfort Visual Analog Scale (Comfort VAS)	-	Force time integral (FTI) comfort levels	Ns/cm <sup>2</sup> score
Surface EMG	Noraxon EMG (Noraxon USA Inc., Scottsdale, AZ, USA)	Root Mean Square (RMS) Reference voluntary contraction (RVC)	uV %
Kinematics (Joint Angles) Motion Analysis	OptiTrack (Natural Point, OR, USA)	Degree	°
Timed up and go test (TUG)	-	functional mobility	sec

At the same time, the sole pressure was measured using a system for measuring the pressure inside the Pedar-X shoes. An examination (Timed Up and Go Test; TUG) of walking for 3 m at a comfortable speed after standing up was performed (Figure 3a,b). Next, 16 markers were attached to the lower extremities. Kinematic data of the movement information, obtained through a three-dimensional movement analysis system (Optitrack 3D Motion Capture System), were measured as a 3-dimensional video. The collected data were stored in a connected computer (Figure 3c). In order to determine the dominant leg, the subjects were asked to kick a ball, and the leg they kicked with was decided as the dominant leg [16]. All of the measurements were carried out three times, with a rest interval of one minute. The average value of the three repetitions was used in the analysis. In order to reduce biases between examiners, one trained examiner performed all of the measurements.



**Figure 3.** Scenes of the experiment: (a,b) System for measuring the pressure inside the Pedar-X shoes and the EMG electrode; and (c) the 3-dimensional movement analysis system (Optitrack 3D Motion Capture System).

In order to confirm the effects of the insole, a system (Novel Corporation, München, Germany) for measuring the pressure inside the Pedar-X shoes was used, which incorporated a sensor and was connected to a data analyzer; in this way, the gait cycle, the





**Figure 5.** Reflection markers used for the 3-dimensional Movement Analysis System (The Optitrack 3D Motion Capture System).

### 2.5. Data Analysis

All of the statistics in this research were handled using the SPSS/PC 19.0 software for Windows (SPSS, Chicago, IL, USA). Regarding the general and specific characteristics of the subjects of the research, through descriptive statistics, the average, standard deviation, percentile frequency, and homogeneity between the two groups were analyzed through Mann–Whitney U and Chi-square tests. The normality of data was examined in all groups using the Shapiro–Wilk test. The data did not follow a normal distribution, so non-parametric tests (Kruskal–Wallis test) were used to analyze inter-group differences and correlations between variables. In order to identify the influence of the shock-absorbing insole for use with HH shoes on walking, regarding the results of the in-shoe pressure measuring system, the Comfort Visual Analog Scale, surface EMG, joint angles motion analysis, and the TUG, descriptive statistics regarding the experimental group and the control group (e.g., average, standard deviation) were obtained, and an independent t-test was conducted. Additionally, the effect size (ES) was calculated using the Cohen’s d statistic. A p-value less than 0.05 was deemed to indicate a significant difference. In order to determine the relationship between the sole pressure variables and the results regarding the feeling when wearing the shoes, Pearson’s product moment correlation coefficient (Pearson’s correlation coefficient) was calculated.

### 3. Results

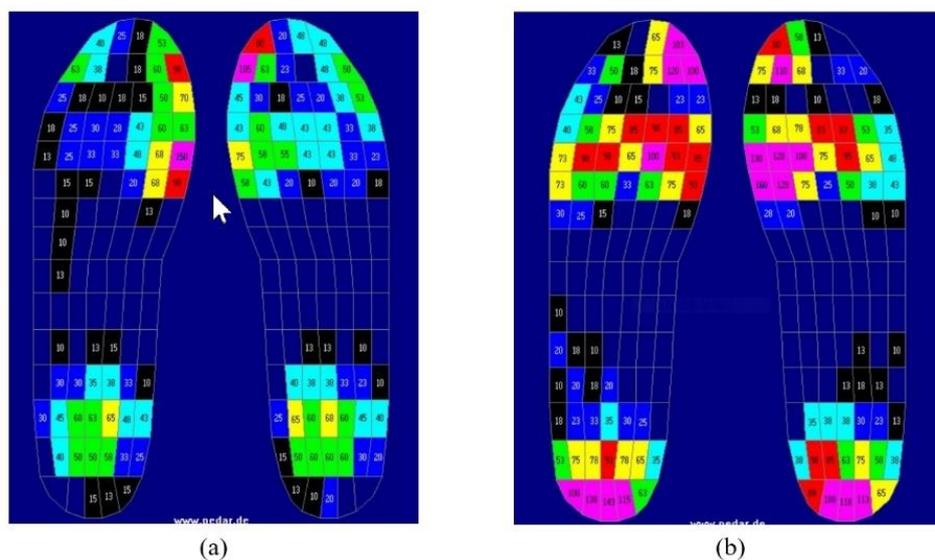
Regarding the subjects who participated in this research, there were a total of 52 women, with 26 participants in the experimental group and 26 participants in the control group. The average age was  $25.38 \pm 8.27$  years old in the experimental group and  $25.31 \pm 7.01$  years old in the control group. The average BMI was  $21.75 \pm 1.99$  years old in the experimental group and  $21.38 \pm 2.26$  years old in the control group. Regarding the international physical activity questionnaire, for the amount of activity, the low physical activity sub-group in the experimental group accounted for 38.46%; meanwhile, in the control group, the moderate physical activity sub-group was high (at 42.31%). There were no significant differences in age, body weight, height, body mass index (BMI), shoe size, and International Physical Activity Questionnaires (IPAQ) between the groups. The result of the timed up and go walking examination (TUG) was  $8.13 \pm 0.98$  s for the experimental group and  $9.13 \pm 1.22$  s for the control group, showing a significant difference ( $p < 0.05$ ; Table 2).

**Table 2.** Demographic characteristics of the participants (n = 52).

		Experimental Group (n= 26)	Control Group (n = 26)	p
Age (years)		25.38 ± 8.27	25.31 ± 7.01	0.973 a
Weight (kg)		57.70 ± 7.49	56.49 ± 8.24	0.598 a
Height (m)		162.62 ± 4.59	162.27 ± 6.26	0.793 a
BMI (kg/m <sup>2</sup> )		21.75 ± 1.99	21.38 ± 2.26	0.578 a
Shoe size		240.00 ± 5.10	239.42 ± 6.53	0.743 a
IPAQ	Low	11 (42.31) c	6 (23.08)	0.574 b
	Moderate	10 (38.46)	11 (42.31)	
	High	5 (19.23)	9 (34.62)	
TUG		8.13 ± 0.98	9.13 ± 1.22	0.004 ** a

\*\**p* < 0.01; Values are presented as mean ± SD for continuous characteristics, and as percentages otherwise. BMI, body mass index; IPAQ, International Physical Activity Questionnaire; TUG, Timed Up and Go Test; a, *p*-value from Mann–Whitney U-test; b, *p*-value from Chi-square test; c, N (%).

Regarding the PP, in the three areas of the toes, the lateral forefoot, and the midfoot, there were significant differences between the group wearing the insoles and the group not wearing the insoles. Furthermore, the CA showed significant differences in the three areas of the medial forefoot, the lateral forefoot, and the midfoot. The force–time integral (FTI) showed significant differences in the six areas of the hallux, the toes, the medial forefoot, the lateral forefoot, the midfoot, and the heels. The ES was the largest for the FTI of the hallux (at 0.503), which denotes the greatest difference between the two groups. The red color in Figure 6 shows the regions with high pressure of the foot (i.e., high foot pressure). Compared to not wearing the insoles, the excessive foot pressure in the front foot area when wearing the insoles was reduced considerably. Overall, a uniform distribution of foot pressure can be observed with use of the insoles (Figure 6, Table 3).



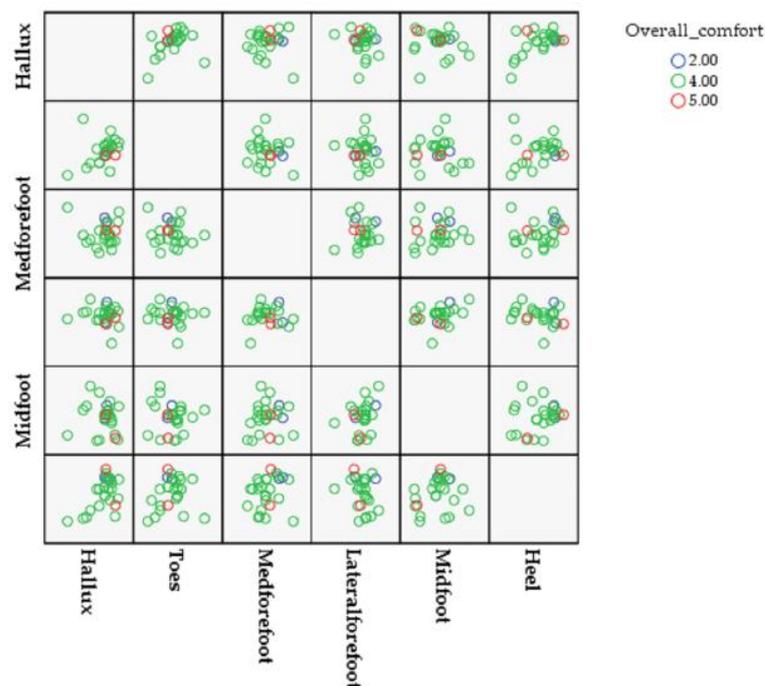
**Figure 6.** Examples of the plantar pressure distribution per region: (a) Wearing the insoles; and (b) not wearing the insoles.

The results for the sole pressure variables, the feeling of wearing the shoes, and the correlations between the variables are shown in Figure 7 and Table 4. Regarding the correlation coefficients between the insole and the kinetic variables, in terms of the average PP value of the heel areas, a moderate positive correlation appeared (*r* = 0.555; *p* = 0.003).

**Table 3.** Plantar foot pressure in high-heel shoes during walking.

		Experimental Group (n = 26)			Control Group (n = 26)			p-Value	ES
		Mean	SD	95% CI	Mean	SD	95% CI		
Hallux	PP (kPa)	110.27	18.05	106.20–114.34	114.67	44.17	104.71–124.63	0.393	0.613
	CA (cm <sup>2</sup> )	8.99	17.08	5.14–12.84	6.26	1.29	5.97–6.55	0.164	0.099
	FTI (Ns/cm <sup>2</sup> )	184.75	53.85	172.61–196.90	209.16	58.56	195.96–222.36	0.005 **	0.503
Toes	PP (kPa)	41.38	14.66	38.08–44.69	50.34	12.86	47.44–53.24	0.000 ***	0.457
	CA (cm <sup>2</sup> )	5.60	5.35	4.40–6.81	5.87	1.55	5.52–6.22	0.678	0.197
	FTI (Ns/cm <sup>2</sup> )	76.07	35.46	68.07–84.06	121.42	38.15	122.82–130.02	0.000 ***	0.311
Medial forefoot	PP (kPa)	109.40	17.40	105.48–113.32	109.86	75.59	92.82–126.90	0.960	0.715
	CA (cm <sup>2</sup> )	13.97	18.44	9.81–18.12	9.21	2.91	8.55–9.86	0.028 *	0.216
	FTI (Ns/cm <sup>2</sup> )	441.60	105.91	417.72–465.48	363.85	97.14	341.95–385.75	0.000 ***	0.492
Lateral forefoot	PP (kPa)	75.94	13.27	72.95–78.93	59.07	43.09	49.35–68.78	0.002 *	0.346
	CA (cm <sup>2</sup> )	12.23	13.24	9.24–15.21	8.85	2.85	8.21–9.49	0.031 *	0.344
	FTI (Ns/cm <sup>2</sup> )	274.12	70.63	258.20–290.05	196.99	75.47	179.97–214.01	0.000 ***	0.430
Midfoot	PP (kPa)	12.20	6.37	10.76–13.63	15.79	8.03	13.98–17.60	0.002 **	0.354
	CA (cm <sup>2</sup> )	3.20	2.42	2.66–3.75	4.38	2.52	3.82–4.95	0.004 **	0.331
	FTI (Ns/cm <sup>2</sup> )	24.96	20.40	20.36–29.56	45.49	26.28	39.57–54.2	0.000 ***	0.297
Heel	PP (kPa)	76.12	22.06	71.14–81.09	86.57	49.19	75.48–97.66	0.106	0.511
	CA (cm <sup>2</sup> )	15.98	16.69	12.21–19.74	14.86	5.54	13.61–16.10	0.575	0.219
	FTI (Ns/cm <sup>2</sup> )	355.34	136.30	324.61–386.07	518.70	192.91	475.21–562.20	0.000 ***	0.478

\*,  $p < 0.05$ ; \*\*,  $p < 0.01$ ; \*\*\*,  $p < 0.001$ ; FTI, force–time integral; MedFF, medial forefoot; CentFF, central forefoot; LatFF, lateral forefoot; ES, Effect Size; CI, 95% confidence interval (lower limit–upper limit);  $p$ -values from Kruskal–Wallis test.



**Figure 7.** Pearson’s correlation coefficients between overall comfort and plantar foot pressure.

**Table 4.** Pearson correlation coefficients (*r*) and *p*-values (*p*) for overall comfort and plantar foot pressure.

Variables	Overall Comfort of EG		Overall Comfort of CG	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Hallux	0.045	0.829	0.382	0.054
Toes	0.337	0.093	−0.174	0.395
Medial forefoot	−0.082	0.691	0.385	0.052
Lateral forefoot	−0.131	0.525	−0.224	0.272
Midfoot	−0.096	0.64	−0.293	0.146
Heel	0.555 **	0.003	−0.049	0.813

\*\**p* < 0.01; EG, Experimental group; CG, Control group.

The gait cycle showed significant differences in the VL, TA, and GA. For the stance period, the GA, the swing period, and the VL, significant differences were also observed. Regarding the %RVC, in the VL and in the GA, significant differences were shown. Regarding the gait cycle, the TA and the GA of the experimental group were more activated. For the stance period, the GA of the experimental group was more activated. For the swing period, the VL of the control group was more activated. Regarding the %RVC, the VL and the GA of the control group were more activated. The ES was the largest for gait cycle of GA (at 0.631), indicating the greatest difference between the two groups (Table 5).

**Table 5.** Muscle activity in high-heel shoes during walking. (unit: uV, %).

Type Event		Experimental Group			Control Group			<i>p</i> -Value	ES
		Mean	SD	95% CI	Mean	SD	95% CI		
Gait Cycle	VL	35.89	11.67	33.09–38.69	42.49	17.27	38.34–46.64	0.015 *	0.431
	TA	341.53	106.48	315.95–367.11	280.79	107.56	254.95–306.63	0.000 ***	0.472
	BF	458.69	172.93	417.15–500.24	496.54	158.51	458.46–534.62	0.179	0.367
	GA	712.65	282.33	787.86–883.81	835.83	199.70	644.82–780.47	0.002 **	0.631
Stances Period	VL	37.42	11.48	34.66–40.18	40.39	13.29	37.20–43.58	0.153	0.450
	TA	342.26	101.61	317.85–366.67	310.09	108.12	284.12–336.07	0.065	0.413
	BF	478.53	115.63	450.75–506.31	510.00	171.11	468.90–551.11	0.192	0.391
	GA	677.72	127.37	695.55–770.98	733.27	157.00	647.13–708.32	0.022 *	0.378
Swing Period	VL	28.53	11.53	25.76–31.30	43.11	14.06	39.73–46.49	0.000 ***	0.473
	TA	357.20	108.65	331.10–383.30	357.16	119.27	328.51–385.81	0.998	0.618
	BF	442.88	155.39	405.55–480.21	435.91	151.00	399.64–472.19	0.783	0.552
	GA	703.02	166.75	662.96–743.07	699.37	131.49	667.78–730.96	0.891	0.328
%RVC	VL	3.00	2.02	2.53–3.49	3.76	1.05	3.51–4.01	0.008 **	0.052
	TA	23.55	6.93	21.89–25.21	22.09	4.89	20.92–23.27	0.136	0.063
	BF	31.10	7.05	27.70–32.98	30.34	11.01	29.41–32.79	0.634	0.008
	GA	50.23	15.54	46.49–53.96	55.91	15.73	52.13–59.68	0.038 *	0.118

\*, *p* < 0.05; \*\*, *p* < 0.01; \*\*\*, *p* < 0.001; TA, tibialis anterior; GA, gastrocnemius; VL, vastus lateralis; BF, biceps femoris; RVC, reference voluntary contraction; ES, Effect Size; CI, 95% confidence interval (lower limit–upper limit); *p*-values from Kruskal–Wallis test.

Regarding the hip joint, a significant difference between Flex-Ext and Int-Ext was observed. The control group displayed movement with a bigger angle. Regarding the knee joint, all three movements showed significant differences. In addition, the experimental group showed movements with larger angles at Flex-Ext and Abd-Add. In contrast, the control group showed movements with bigger angles at Int-Ext. Regarding the knee joint, Abd-Add in the control group showed movement with a bigger angle. The ES was moderate for flexion–extension of the hip, at 0.253 (Figure 8, Table 6).

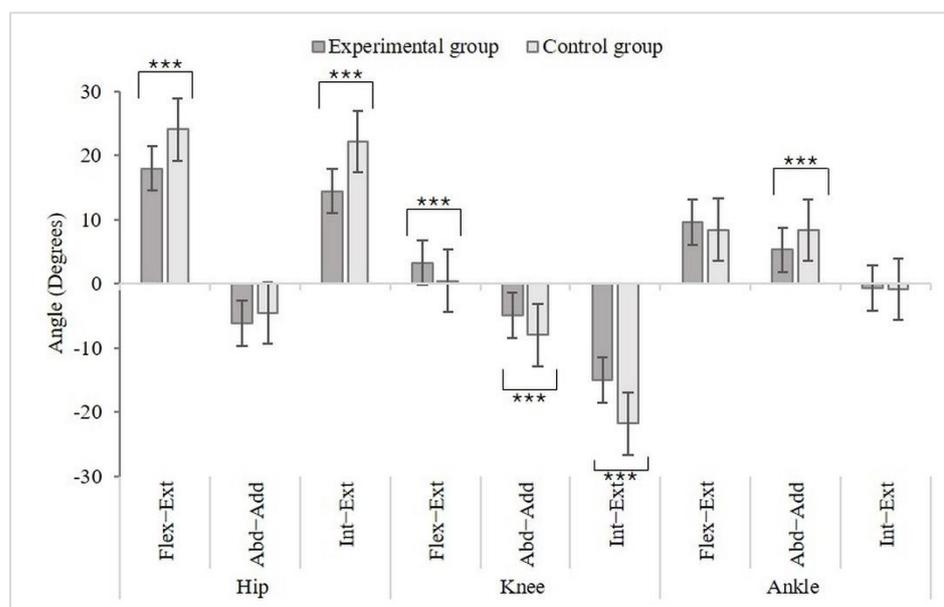


Figure 8. The joint angles for the hip, knee, and ankle during walking. **\*\*\***,  $p < 0.001$ .

Table 6. The joint angles for the hip, knee, and ankle during walking (degree).

		Experimental Group			Control Group			p-Value	ES
		Mean	SD	95% CI	Mean	SD	95% CI		
Hip	Flex-Ext	3.28	6.43	1.83-4.73	0.42	2.54	-0.15-0.99	0.000 <b>***</b>	0.253
	Abd-Add	-4.94	2.85	-5.58-4.30	-7.99	5.15	-9.15-6.83	0.055	0.319
	Int-Ext	-15.08	9.8	-17.29-12.87	-21.84	5.68	-23.12-20.56	0.000 <b>***</b>	0.104
Knee	Flex-Ext	9.53	4.16	8.59-10.47	8.4	4.23	7.44-9.35	0.000 <b>***</b>	0.017
	Abd-Add	5.25	2.97	4.58-5.92	8.34	4.6	7.31-9.38	0.000 <b>***</b>	0.013
	Int-Ext	-0.64	2.65	-1.24-0.04	-0.89	2.3	-1.41-0.37	0.000 <b>***</b>	0.003
Ankle	Flex-Ext	17.98	4.17	17.04-18.92	24.01	5.09	22.86-25.15	0.100	0.260
	Abd-Add	-6.22	3.76	-7.07-5.37	-4.61	6.26	-6.02-3.20	0.000 <b>***</b>	0.198
	Int-Ext	14.44	9.97	12.19-16.68	22.15	5.18	20.99-23.32	0.486	0.158

**\*\*\***,  $p < 0.001$ ; ES, Effect Size; CI, 95% confidence interval (lower limit-upper limit);  $p$ -values from Kruskal-Wallis test.

The results of a comfort test after walking are provided in Figure 9. For the overall feeling of wearing the shoes and at the forefoot, the comfort results for the group wearing the insoles were significantly higher ( $p < 0.05$  and  $p < 0.001$ , respectively).

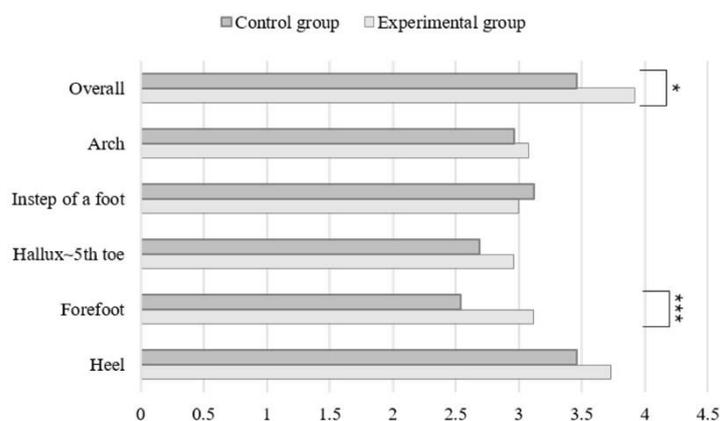


Figure 9. Comfort Visual Analog Scale (VAS) after walking. Statistical analysis by Kruskal-Wallis test; \*,  $p < 0.05$ ; **\*\*\***,  $p < 0.001$ .

#### 4. Discussion

Regarding the purpose of this research, through kinetic analysis of a shock-absorbing insole for use with HH shoes that effectively offsets the negative influence of wearing the HH shoes, in order to determine the influence on walking while alleviating the impact force through a re-distribution of the sole (plantar) pressure, the plantar pressure (in-shoe plantar pressure), surface EMG, gait, subjective comfort, and functional mobility were compared and analyzed.

Regarding the TUG—an examination that measures dynamic balance and movement capability [22]—the proposed shock-absorbing insoles for use with HH shoes improved the stability of the posture, compared to the case when not wearing the insoles. In addition, the walking speed increased. This is consistent with the result that insoles improve somatosensory function, and can be useful in alleviating age-based damage in the adjustment of balance [23]. Regarding the proposed shoe insoles, the mechanism by which the posture control is enhanced has been confirmed in previous research [24].

From the results of this research, regarding the FTI, the pressure of the group wearing the insoles decreased significantly in four areas—the hallux, toes, midfoot, and heels—relative to the group that did not wear the insoles. In contrast, regarding the two areas of the medial forefoot and the lateral forefoot, the pressure of the group wearing the insoles increased significantly, compared to the group not wearing the insoles. This was attributed to the shock-absorbing insole dispersing the pressure. The measurement results showed that the shock-absorbing insole considerably weakened the PP in the heels and the front foot parts. In addition, the increase in the area of contact of the midfoot domain to successfully redistribute the pressure was consistent with a study highlighting the important changes in the domain of the mid-foot [8].

The insole also reduced the heel pressure, the medial forefoot pressure, and impact force to the foot. This also coincided with a preceding study showing that insoles provide higher perceived comfort [7], as well as in agreement with a study reporting that, when insoles are used, the maximum impact force [25] and the loading rate [26] between the feet, the ground, and the knees may be effectively decreased. In addition, regarding individuals who have diverse pathologies (including knee pain), the efficacy of insoles in reducing the pain and the maximum impact force has been demonstrated in a previous study [27].

As a result of this research, regarding the feeling of wearing the shoes, the average pressure value and that in the heel part were high. Hence, in order to heighten the feeling of wearing the shoes, decreasing the pressure at the heel is important. If the insoles are used, together with sole pressure, as the impact force to the feet is decreased greatly, higher comfort can be perceived [1,25]. Regarding the VL, in the gait cycle, swing period, and %RVC, the group not wearing the insoles had higher activation than the group wearing the insoles. Regarding the TA and the GA, in the gait cycle, the group wearing the insoles was activated more than the group not wearing the insoles. When compared with the group not wearing the insoles, regarding the HH shoes, the %RVC of the VL and the GA was decreased. This coincided with a study reporting that the insole influences EMG activity in the lower extremities [6]. When wearing shock-absorbing insoles, due to increased ankle plantar flexion, in order to prevent a weight shift to the front, the TA muscle was activated more [28].

Furthermore, for the GA, the group not wearing the insoles showed higher activation. Regarding this, in a previous study, it has been reported that wearing high heels decreases stability through the imbalance of the muscles of the feet and the ankles by increasing the muscle activity of the GA. It was also reported that this can cause overall musculoskeletal system problems [29]. As a result, through activation changes of the TA muscle and the GA, by heightening the stabilities of the feet and the ankle joints, the walking pattern was improved. This could also prevent potential injury of the lower extremities.

The changes in the ankle dynamics and kinematics due to wearing HH shoes increase ankle instability and the danger of injury to the lower extremities [30]. From the results of this research, at the hip, the knee, and the ankle joint, the group not wearing the insoles

showed movement with an overall larger angle, compared to the group wearing the insoles. Accordingly, wearing the shock-absorbing insoles improved the postural stability when walking. In addition, the pressure was dispersed, including the heel pressure and the medial front foot pressure, the impact force was decreased, and walking speed was increased. Due to this, higher comfort could be felt.

A limitation of this research is that it did not consider that the PP, the maximum strength, and the CA increased differently in specific domains, according to differences in the speed of movement of the subjects, although the participants were instructed to walk at their most comfortable walking speed. As a result, in future research, the speed of movement when walking (e.g., at comfortable walking speeds of 0.83–1.11 m/s) should be considered. Furthermore, in future work, the effect of the shock-absorbing insole should be verified not merely for walking, but also in other everyday life movements. Based on the results of this research, improvement of the awareness of the side-effects related to wearing HH shoes and the need for appropriate education for prevention should be emphasized.

## 5. Conclusions

The purpose of this research was to identify the influence of proposed shock-absorbing insoles for use with HH shoes on walking. To this end, the results of a plantar foot pressure analysis (via in-shoe plantar pressure), surface EMG, walking (gait) analysis, and subjective comfort and functional movement assessments were compared and analyzed. Wearing the shock-absorbing insoles improved the postural stability of participants when walking. In addition, their walking speed was increased. The heel pressure, medial front foot pressure, impact force experienced, etc., were also dispersed. For these reasons, higher comfort was reported. Through activation changes of the TA muscle and the GA, the stability of the ankle joint was heightened. In the future, the effect of the shock-absorbing insole for use with HH shoes should be verified not only when walking, but also in other everyday life movements.

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