Arch Health Sci Res. 2022;9(3):186-192
DOI: 10.5152/ArcHealthSciRes.2022.21148

Original Article

Evaluation of the Effect of Different Height Heel Wedges on Postural Stability and Plantar Pressure in Women with Genu Recurvatum

Naile Hande YAZICI, Esra ATILGAN

Department of Orthotics and Prosthetics, İstanbul Medipol University, Faculty of Health Sciences, İstanbul, Turkey

Cite this article as: Yazıcı NH, Atılgan E. Evaluation of the effect of different height heel wedges on postural stability and plantar pressure in women with genu recurvatum. *Arch Health Sci Res.* 2022;9(3):186-192.

ABSTRACT

Objective: In mild cases of genu recurvatum, normal alignment can be achieved by using orthotic heel wedges, as a conservative treatment. The aim of this study is to analyze the instant effects of heel wedges of different heights on postural stability and plantar pressure by changing the angle of hyperextension in healthy women with genu recurvatum.

Methods: Twenty-eight healthy women between the ages of 20 and 35 were included into the study. Recurvatum angles were measured by using standard goniometer and College des Jeunes Orthopedistes application. Individuals with a hyperextension angle between 10° and 15° were included in the study. Static and stabilometric data were recorded by the Sensor Medica baropedography device. Analyses were carried out on barefoot and wedges of 1 cm, 2.5 cm, and 5 cm.

Results: In the static analysis, a positive significant difference was found between barefoot and 2.5 cm wedge in the parameters of left and right forefoot and rearfoot load, forefoot weight ratio, rearfoot surface, total surface, average pressure, maximum pressure, left forefoot surface ($P < .05$). In the stabilometric analysis, a positive significant difference was found between the barefoot and 2.5 cm wedge, and swing length was decreased in both eyes open and closed conditions ($P < .05$).

Conclusion: In our study, the 2.5 cm wedge brings the knee angle closer to the anatomical angle than the 1 cm and 5 cm wedges and has positive effects on plantar pressure and stability. According to the findings, we recommend that individuals with 10°-15° recurvatum use a 2.5 cm wedge in their shoes.

Keywords: Genu recurvatum, heel wedge, plantar pressure, postural stability

Introduction

Closed kinetic chain refers to a position where the most distal of a given extremity is fixed to a solid object. This position alters the movement of the joints and surrounding musculature up the chain.[1] When the body is considered as a closed kinetic chain, the biomechanical change occurs ring in any segment affects the alignment. Deformities of the lower limbs or spine can alter the normal biomechanics of the entire body and alter the ground reaction force (GRF) of the knee, hip and ankle joints.[2]

Genu recurvatum (GR) is defined as the extension more than 5° of the knee on the sagittal plane.[3] There is no consensus about the limits of "normality" of knee joint extension. Knee extension should be limited to a maximum of 10°-15° in order to be considered normal. Knee with more than 15° of extension is considered as pathologic.[3] Physiological GR is commonly asymptomatic, bilateral, and symmetrical.[4]

Multiple factors can cause GR, including weakness of the muscles around the knee joint, excessive plantar flexion, a proprioceptive disorder, spasticity of the quadriceps, and neurological or musculoskeletal injury.[5] Genu recurvatum is typically associated with weight-bearing activities. The GRF vector that acts anterior to the knee joint increases stress on the passive restraining structures that resist further knee extension. The asymptomatic form of the GR is associated with capsuloligamentous laxity and specifically the oblique popliteal ligament that restraints knee hyperextension. Individuals can be considered healthy despite the presence of capsular ligamentous hyperlaxity.[6] In healthy individuals, impaired alignment at knee can also cause pain in the knee and inflammatory problems such as osteoarthritis in the future.[7] Among the factors affecting

Corresponding author: Naile Hande YAZICI, e-mail: nhyazici@medipol.edu.tr

Received: January 16, 2022
Accepted: August 1, 2022

knee alignment, demographic factors are also included in the studies. The anatomical angle of the knee in women is higher than in men, especially due to the anatomical structure of the pelvis.[8] Therefore, GR is more common in women than in men.[9] Therefore, we included women in our study.

The knee biomechanics are attempted to be corrected first through the orthotic treatment that is applied to individuals who have a GR deformity. The required tibial angle to prevent hyperextension can be obtained with heel wedges. The usage of a heel wedge will increase the shank to a vertical angle, thereby advancing the knee and hip joints. This may facilitate the alignment of the GRF behind the hip joint and the middle of the knee joint and optimize the extensor moment of the knee preventing hyperextension. Thus, body's center of gravity is displaced and stability is increased.[10]

Genu recurvatum deformity shifts the mechanical axis of lower extremity posteriorly which may disturb the balance and lead to injury.[11] Ankle and hip strategies are used to control posture sway, and the knee joint located between them is a part of a kinetic chain. Sway motion controls contractions of the ankle joint muscles, and the cooperative reaction of muscles near the knee joint provides postural stability.[12] Ankle stabilization could contribute to avoiding potential compensating coronal plane movements in the foot and/or ankle joint, thereby increasing the effect of wedges in knee joint unloading.[13]

The closed kinetic change in the chain affects the pressure distribution and postural stability.[14] Genu recurvatum deformity changes GRF, and this affects the distribution of plantar pressure. This means that different pressures may occur in different areas of the foot, affecting the biomechanical function of the lower extremity. Studies have shown that GR deformity reduces static and dynamic postural stability. Moreover, it was concluded that anteroposterior stability increased in individuals with GR, but no changes occur in mediolateral and other stability indexes.[15] Rabusin et al's[16] meta-analyses analyzed the effects of heel wedges on lower extremity biomechanics and muscle function. The findings showed that heel wedges affect certain lower extremity biomechanical and muscle function parameters during walking and running and that the height and stiffness of the heel wedge caused a reduction in maximal plantar pressure, especially in the rearfoot.

As seen in the literature, knee deformities can affect plantar pressure distribution and stability. At the same time, few studies have investigated GR in healthy individuals. Thus, our study was carried out to examine the instant effect of heel wedges of different heights on postural stability and plantar pressure in healthy women with GR.

Methods

The study is executed concurrently with Helsinki Declaration Principles and was approved in the assembly of Istanbul Medipol University Non-Entrepreneurial Clinical Studies Ethical Committee dated August 29, 2019, with the case number of 10840098-604.01.01-E.45463 and the resolution number of 633. The volunteers were informed about the purpose and duration of the study, the measurement parameters to be applied, and the questionnaires; after reading and signing the "Informed Volunteer Form," their consent was obtained.

During the study, demographic information including age, gender, height, body mass, and GR angle was recorded. Extension angles were measured using standard goniometer and College des Jeunes Orthopedistes (CJOrtho) mobile application. In the pedobarographic assessment, static and stabilometric analysis was performed with bare feet and wedges of width 1 cm, 2.5 cm, and 5 cm. Analysis results were recorded on the computer with the freeStep (Rome, Italy) software integrated into the system. For accuracy and reliability, all measurements and evaluations were completed by the same researcher and detailed information about the study was given (first author N.H.Y.).

Subjects

Thirty-six women with GR deformity who applied to Istanbul Medipol University Prosthetics Orthotics Center voluntarily participated in this study. Twenty-eight of them were included in the study after evaluation. The study took place between November 2019 and March 2020. Individuals aged between 20 and 35, with bilateral recurvatum angles between 10° and 15°, without any spine, hip, knee, and ankle physical, orthopedic, or neurological disorders, disability, or chronic disease were included in the study. Individuals with recurvatum angles less than 10° and greater than 15,° with foot deformity (pes planus, pes cavus, pes varus, etc.), anterior cruciate ligament injuries, knee joint instability, or pain from any cause, and those who were pregnant were excluded.

Measurement of the Angle of Extension by Standard Goniometer and College des Jeunes Orthopedistes (CJOrtho) Mobile Application

Knee extension was first measured by the standard goniometric procedure. Participants were in prone position, the goniometer axis was positioned over the lateral joint line, the stationary arm was aligned with the greater trochanter, and the movable arm was aligned with the lateral malleolus.[17]

The CJOrtho application was used for the second measurement. Milani et al[18] reported that measurements obtained using a smartphone's digital goniometer were reliable for repeated knee range of motion measurements and had less variance than a standard goniometer. The validity of virtual goniometry was determined by comparing it to clinical goniometry.[19] Other than reproducibility, such a tool helps to improve the reliability of the examination for clinicians in training or with minimal experience.[19] The application was first created with the purpose of educating health professionals. This application includes a lot of features such as categorization systems for trauma and orthopedics, result scores for clinic and radiology, databases for the keeping of collected data, and a goniometer. The application includes 20 result scores. The result scores are divided into general and specific evaluations.[20]

Participants were instructed to stand in their normal stance, and their feet were open in the length of their shoulders. While the individuals were standing in this position, trochanter major, lateral condyle of femur, and lateral malleolus were determined as reference points.

The recurvatum angle was measured by combining the reference points over the application. Photographs were taken from the sagittal plane through a smartphone. The phone was immobilized through a tripod vertically to the ground. The camera's lens was positioned on the level of the participant's knee joint center in a way that it would stand between the center point of the tripod's feet, 3 m away from the participant, and about 80 heights.[21] The recurvatum angles measurements were made 4 times, once for each of the following: barefoot and when the participants were on 1 cm, 2.5 cm, and 5 cm wedges placed on a flat floor. All measurements were taken barefoot. After each photography session, a 1-minute resting break was taken.

Design of Heel Wedge Orthosis

Wedges are orthotic parts that raise the heel equally from the medial and lateral sides and bring the ankle plantar flexion.[22] In our study the heel wedges were created by combining different thicknesses of 30 Shore ethyl vinyl acetate (EVA) and shaped on a milling machine (Figure 1). Ethyl vinyl acetate is a durable, flexible, and lightweight microcellular material.[23] The heel wedges from the rear foot to the midfoot are of equal height from the lateral and medial, and the

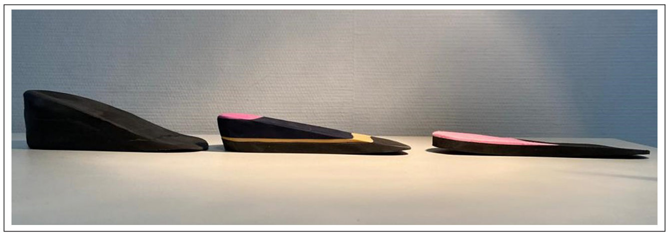

Figure 1. Side view of 1 cm, 2.5 cm, and 5 cm heel wedges made of EVA. EVA, ethyl vinyl acetate.

height decreases from back to front. Wedge angles were measured at 5°, 11°, and 19°, using the app named "Measure" on the iPhone mobile phone (Figure 2a-c). The wedges were made by a specialist orthotist using classic methods at the Prosthetics Orthotics Center.

Pedobarographic Analysis: Static Plantar Pressure and Postural Stability Measurement

Sensor Medica Baropedography Device (Guidonia Montecelio, Roma, Italia)

Baropodometry or pedobarography devices, which enable the assessment of static and dynamic posture and gait, as well as allowing for the testing of load distribution and balance, are objective and reproducible measurement instruments.[24]

Freemed© Maxi model baropodometric platform is a plantar pressure distribution analysis device that has 50 × 60 cm measurements, aluminum parts for its pressure platform, 8 mm thickness, 3000 sensors, and a sensor lifetime of 1.000.000 cycles, 2.5 dpi XY, 400 hz frequency, 8-bit Z resolution, and that can measure 150 N/cm² pressures (https://www.sensormedica.com/download/DataSheet/Freemed.pdf). FreeStep v. 1.0.3 is a software with central database that includes static and dynamic baropodometric, stabilometric analysis, movement analysis, morphologic video analysis, digital pedograph, Romberg test, statistical analysis, and automated reports.[25]

Plantar pressure and postural stability measurements were executed through the freeStep software of Sensor Medica baropedography device. Baropedographic measurement occurred through static and stabilometric analysis.

During the analysis, the participants were positioned in a static position with the aid of the apparatus placed on the sensor plate platform in a static position in which the angle between their feet would be 30° and the distance between their heels would be 2 cm.[26] Static analysis was executed for 5 seconds with eyes open; stabilometric analysis on the other hand was executed for 52 seconds twice: first with opened eyes and then again with closed eyes.

In the static analysis, forefoot plantar contact surface (cm^2), rearfoot plantar contact surface (cm^2), forefoot load (%) and rearfoot load (%), forefoot average weight ratio (%), rearfoot average weight ratio (%), total plantar contact surface (cm^2), total load (%), and average pressure (kg/cm^2) and maximum pressure (kg/cm^2) parameters were analyzed.[27,28]

The images provided by the software are diversified: plantar areas with high pressure are highlighted by shades of orange to red, medium pressure areas are yellow, and areas with low pressures are in green, blue, and purple. There is also the variant of detailed zonal representations, each small area having a number from 9 (maximum) to 0 (minimum) pressure, each number being colored according to the intensity of the represented pressure.[28] This is divided into the right and left feet and subdivided into the forefoot and rearfoot, which allows the measurements of the percentage of weight supported by each foot and the contact surface of each part.[29]

In the stabilometric analysis, in the eyes' open/closed positions, sway length (mm), ellipse surface (mm^2), delta X (laterolateral average) (mm), and delta Y (anteroposterior average) (mm) parameters were analyzed.[26,27]

The smaller the ellipse area, the greater the stability of the patient, delta Y (the Center of Pressure (CoP) rate in the anteroposterior direction) and delta X (the CoP rate in the mediolateral direction) parameters refer to the CoP deviation degree from the positioning parameters.[29]

Analyses were made 4 times, once for each of the following: barefoot and when the participants were on 1 cm, 2.5 cm, and 5 cm wedges placed on a flat floor. All analyses were taken barefoot. After each photography session, a 1-minute resting break was taken.

Three attempts of each test were recorded. Before recording, participants were asked to stand as still as possible.[30] Preliminary practice trials were performed to ensure that the participants felt comfortable with the test conditions and understood the instructions. Normal values and abnormal deviations were detected.

Statistical Analysis

Sample size was calculated with G*power program. Statistical power analyses were used to determine the optimum sample size by using sway length in the open-eyes condition with bare feet in the stabilometric analysis parameter. As a result of the power analysis based on the primary outcome, the sample number necessary to be included in the study is determined as a minimum of 28. In the analysis of the data obtained from the study, the alpha level used in determining the sample size was 0.05, and the ideal power was considered to be 80%. Effect size (Cohen's d) value was calculated, and 0.68 was accepted according to the reference.

Figure 2. a-c (a) Measurement of the angle of the 1 cm wedge by application. (b) Measurement of the angle of the 2.5 cm wedge by application. (c) Measurement of the angle of the 5 cm wedge by application.

Table 1. Demographic and Clinical Characteristic of Participants

	Mean ± SD	Minimum	Maximum
Age (years)	23.03 ± 2.13	20	30
Height (cm)	164.07 ± 5.61	154	175
Weight (kg)	62.10 ± 13.89	45	108
BMI (kg/m^2)	23.09 ± 4.60	17	38
Angle of genu recurvatum (°)			
Right	12.89 ± 1.25	10	14
Left	11.21 ± 1.57	10	14

SD, standard deviation; BMI, body mass index.

The data analysis of the study's results is made through the statistics program "Statistical Package for Social Sciences" (SPSS) Version 22.0 (SPSS inc., IBM Corp., Armonk, NY, USA). The numerical data is stated as n (%), measurement data is stated as arithmetic average ± standard deviation (X ± SD). Statistical significance level is accepted as $P < .05$ in all analyses. Non-parametric tests were applied since case numbers were 30 and below. In order to exhibit the difference between 2 dependent variables in the analyzed data, Wilcoxon signed rank test was applied.

Results

The average age of 28 women participating in the research was detected as 23.03 ± 2.13 years, average height as 164.07 ± 5.61 cm, average weight as 62.1 ± 13.89 kg, body mass index average as 23.09 ± 4.6 kg/m^2, right GR angle as 168.89 ± 1.25, and left GR angle as 169.21 ± 1.57. The demographic and clinical characteristics of the participants are shown in Table 1.

The mean values and SDs of the plantar pressure and stabilometric data of the 1 cm, 2.5 cm, and 5 cm wedges are shown in Table 2.

No significant difference was detected between the data for the right fore and rearfoot load, right forefoot contact surface, right fore and rear foot weight ratio, right and left foot total contact ratio, total load,

Table 2. Plantar Pressure and Stabilometric Analysis Data of the Participants with Bare Feet and 1 cm, 2.5 cm, and 5 cm Wedge

		Barefoot	1 cm Wedge	2.5 cm Wedge	5 cm Wedge
Plantar Pressure Analysis Data		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Forefoot load (%)					
Right		19 ± 3.8	17.96 ± 3.83	16.64 ± 5.41	17.10 ± 4.64
Left		20.82 ± 5.72	1810 ± 4.83	16.07 ± 3.39	16.89 ± 4.29
Rearfoot load (%)					
Right		30.50 ± 4.29	32.03 ± 5.65	33.32 ± 6.03	32.85 ± 5.3
Left		29.32 ± 5.5	31.89 ± 5.61	33.6 ± 4.7	33.5 ± 3.72
Total load (%)					
Right		49.5 ± 3.58	50 ± 4.7	50.35 ± 4.6	49.6 ± 4.03
Left		50.64 ± 3.72	50 ± 4.7	49.64 ± 4.69	50.39 ± 4.03
Forefoot weight ratio (%)					
Right		38.32 ± 6.97	36.39 ± 8.08	33.89 ± 9.91	34.14 ± 10
Left		41.92 ± 10.4	36.17 ± 9.43	32.53 ± 6.21	33.64 ± 6.98
Rearfoot weight ratio (%)					
Right		61.67 ± 6.97	63.64 ± 8.09	66.07 ± 9.9	65.35 ± 9.45
Left		58.07 ± 10.4	63.82 ± 9.43	67.53 ± 6.29	66.85 ± 7.64
Forefoot surface (cm^2)					
Right		49.67 ± 6.97	45.64 ± 13.22	46.32 ± 8.32	46.17 ± 11.45
Left		51.07 ± 15.93	44.53 ± 13.51	44.10 ± 9.45	43.96 ± 10.35
Rearfoot surface (cm^2)					
Right		45.96 ± 8.1	52.32 ± 7.01	65.71 ± 8.52	65.5 ± 7.73
Left		45 ± 8.51	52.57 ± 8	65.96 ± 7.49	65.5 ± 6.42
Total surface (cm^2)					
Right		95.6 ± 22.62	97.92 ± 18.27	112.10 ± 12.92	111.67 ± 17.17
Left		96.07 ± 22.6	97.32 ± 19.55	110.21 ± 15.35	109.5 ± 14.59
P. max (g/cm^2)					
Right		783.64 ± 145.96	680.78 ± 170.12	573.85 ± 79.69	613.82 ± 102.11
Left		756.64 ± 131.81	703.46 ± 114.14	556.75 ± 67.98	617.78 ± 78.66
P. avg (g/cm^2)					
Right		327.21 ± 66.95	316.32 ± 50.71	275.03 ± 43.49	274 ± 40.56
Left		330.6 ± 55.21	318.78 ± 50.47	276.71 ± 42.26	282.17 ± 33.61
Stabilometric analysis data					
Open eyes	Sway length (mm)	672.06 ± 232.58	639.47 ± 221.5	525.08 ± 198.25	613.73 ± 207.85
	Ellipse surface (mm^2)	74.61 ± 64.01	98.78 ± 126.21	55.47 ± 40.59	89.18 ± 67.43
	Delta X	10.44 ± 5.06	12.01 ± 9.36	8.62 ± 3.62	10.66 ± 5.33
	Delta Y	11.25 ± 4.51	13.14 ± 10.23	10.12 ± 5.03	11.5 ± 5.55
Closed eyes	Sway length (mm)	692 ± 271.53	645.71 ± 225.41	569.66 ± 184.48	631.66 ± 182.28
	Ellipse surface (mm^2)	125.76 ± 203.24	84.89 ± 122.55	74.62 ± 49.39	66.78 ± 45.48
	Delta X	12.37 ± 16.8	11.66 ± 13.53	13.39 ± 11.86	10.85 ± 5.43
	Delta Y	13.69 ± 12.23	12.64 ± 10.31	14.32 ± 12.75	12.55 ± 7.19

P, pressure; Avg., average; delta X, laterolateral mean; delta Y, anteroposterior mean.

Table 3. Comparison of Plantar Pressure Analysis Data of the Participants with Bare Feet and 1 cm, 2.5 cm, and 5 cm Wedge

	1 cm Wedge		2.5 cm Wedge		5 cm Wedge	
	z	*P*	z	*P*	z	*P*
Right forefoot load (%)	−1.136	.256	−2.497	.013*	−2.040	.041*
Left forefoot load (%)	−3.118	.002*	−3.742	.000*	−2.850	.004*
Right rearfoot load (%)	−1.376	.169	−2.587	.010*	−2.058	.040*
Left rearfoot load (%)	−2.738	.006*	−3.129	.002*	−3.373	.001*
Right foot total load (%)	−0.598	.550	−1.248	.212	−0.013	.989
Left foot total load (%)	−0.734	.463	−1.401	.161	−0.202	.840
Right forefoot weight ratio R/F (%)	−1.016	.310	−2.711	.007*	−2.098	.036*
Left forefoot weight ratio R/F (%)	−3.643	.000*	−3.921	.000*	−3.292	.001*
Right rearfoot weight ratio R/F (%)	−1.016	.310	−2,712	.007*	−1.950	.051
Left rearfoot weight ratio R/F (%)	−3.643	.000*	−3.978	.000*	−3.589	.000*
Right forefoot surface (cm²)	−2.041	.410	−1.265	.206	−1.359	.174
Left forefoot surface (cm²)	−3.741	.000*	−3.190	.001*	−2.898	.004*
Right rearfoot surface (cm²)	−4.263	.000*	−4.606	.000*	−4.603	.000*
Left rearfoot surface (cm²)	−4.356	.000*	−4.628	.000*	−4.625	.000*
Right foot total surface (cm²)	−1.042	.297	−3.815	.000*	−3.566	.000*
Left foot total surface (cm²)	−0.813	.416	−4.328	.000*	−3.521	.000*
Right foot P. max (g/cm²)	−2.869	.004*	−4.554	.000*	−3.917	.000*
Left foot P. max (g/cm²)	−1.822	.680	−4.469	.000*	−4.053	.000*
Right foot P. avg (g/cm²)	−1.048	.295	−3.769	.000*	−3.496	.000*
Left foot P. avg (g/cm²)	−1.264	.206	−4.202	.000*	−3.860	.000*

*$P < .05$. R, right; L, left; P, pressure; Avg., average.

average pressure, and left foot maximum pressure when the static plantar pressure analysis was compared in the case of the individuals' usage of a wedge of 1 cm ($P > .05$). A significant difference was detected between the data for right and left fore and rearfoot load, rear and forefoot weight ratio, rearfoot contact surface, total contact surface, average pressure, maximum pressure, and left forefoot contact surface when static plantar pressure analysis was compared in the case of the individuals' usage of a wedge of 2.5 cm ($P < .05$). No statistically significant difference was detected between the data for right forefoot contact surface, right and left foot total load, and rearfoot weight ratio when the static plantar pressure analysis was compared in the case of the individuals' usage of a wedge of 5 cm ($P > .05$). The relationship between individuals' plantar pressure analysis with bare feet and plantar pressure analysis with 1 cm, 2.5 cm, and 5 cm wedge is shown in Table 3.

When the stabilometric analysis data of individuals with bare feet and using 1 cm and 5 cm wedges were compared, there was no statistically significant difference found between the data ($P > .05$). A statistically significant difference was found between oscillation lengths with eyes open and closed with 2.5 cm wedge ($P < .05$). There was no statistically significant difference found between elliptical surface, delta X, and delta Y with eyes open and closed ($P > .05$). The relationship between the stabilometric analysis of individuals with bare feet and the stabilometric analysis data with 1 cm, 2.5 cm, and 5 cm wedge is shown in Table 4.

Discussion

The deformity occurring in any segment of the body affects the entire body alignment through kinetic chain. In order to correct the body alignment, one might resort to orthosis as a conservative treatment. Orthosis that is applied to the feet might correct the body alignment and allow the GRF vector to pass through the correct place biomechanically. Application of wedge aims to create the desired effect on the area of correction by creating different momentums. Accordingly, our study aims to analyze the instant effect heel wedges of 1 cm, 2.5 cm, and 5 cm have on plantar pressure analysis and postural stability in women with GR.

Increase in heel height during standing up or walking may disrupt the body's balance by affecting certain lower extremity biomechanics and muscle function parameters.[31] Zhang et al[32] included 15 healthy men in their study, which they thought would increase stability and comfort with an arch-supported heel wedge compared to a heel wedge without an arch support. The heel wedges are of 2.5 cm height and made of EVA. Footscan® pressure plate was used to record the center of pressure coordinates at a measurement, and Infoot 3D foot scanning system

Table 4. Comparison of Participants' Barefoot and Stabilometric Analysis Data with 1 cm, 2.5 cm, and 5 cm Wedge

		1 cm Wedge		2.5 cm Wedge		5 cm Wedge	
		z	*P*	z	*P*	z	*P*
Open eyes	Sway Length (mm)	−0.820	.412	−2.938	.003*	−1.207	.227
	Ellipse surface (mm²)	−0.182	.855	−1.799	.072	−1.025	.305
	Delta X (mm)	−0.547	.585	−1.412	.158	−0.091	.927
	Delta Y (mm)	−0.273	.785	−1.617	.106	−0.137	.891
Closed eyes	Sway length (mm)	−0.159	.873	−2.141	.032*	−0.501	.616
	Ellipse surface (mm²)	−0.319	.750	−0.091	.927	−0865	.387
	Delta X (mm)	−0.205	.838	−0.455	.649	−0.660	.509
	Delta Y (mm)	−0.228	.820	−0.148	.882	−0.137	.891

*$P < .05$. Delta X, laterolateral mean; delta Y, anteroposterior mean.

was used to capture foot dimensions. When the study's findings were analyzed, it was found that adding an arch support reduces the displacement and velocity of MedioLateral Center of Pressure (ML- CoP) during walking and also improves mediolateral stability and comfort.

Siqueira et al[33] tested the postural stability of 23 healthy women with knee hyperextension, a demographic similar to our study, with AMTI force plate on foam (Airex balance pad®) and bare feet with open and closed eyes. As a result of this study, it was stated that in order to prevent injuries related to hyperextension and to ensure the correct alignment in knee hyperextension, postural stability in standing up position must be taken into consideration. In our study, when bare feet and 2.5 cm wedge were compared, a decrease in sway length in the case of open and closed eyes was observed. We think that in order to prevent injuries related to hyperextension, usage of a wedge of 2.5 cm is effective since it affects postural stability positively and decreases the weight load on the knees.

Zhang et al[34] in their study used heel wedges made by EVA which were 2.5 cm in height, metatarsophalangeal, arc supported, extending to the back of the joint, and had a stiffness of 32 shores. The wedge was remodeled in Delcam Powershape software after the participants' feet were scanned with the foot scanning system Infoot 3D while they were in a neutral position on the wedge. Individuals' walking cycle with a wedge that is modeled in the computer environment was evaluated with a Footscan® pressure plate. The results of the study indicate that a wedge enhances foot pressure distribution and increases stability. The results of this study show similarities to our study.

Zhang and Li[31] investigated the effects of using shoes, shoes + 16 mm, 25 mm, and 34 mm wedges, and shoes + soft and hard heel wedge on plantar pressure and mediaolateral center of pressure motion during walking.They found of this study suggest that thick heel wedges should be used with caution, and that a heel lift made of materials with good support and elastic properties might be more appropriate to improve footwear comfort and mediaolateral motion control. Similar to these studies, 1 cm and 2.5 cm wedges were used in our study. Furthermore, 5 cm wedges were also added because of some women prefer high heels. In addition, supportive of the conducted studies, 30 Shore EVA of middle stiffness was used as the wedge material in our study.

In our study, plantar pressure and postural stability were examined with heel wedges at different heights. It is observed that wedges of 1 cm and 5 cm did not significantly affect postural stability and the wedge of 2.5 cm positively affected the sway length. Significant effects were observed on pressure distribution and load as a result of the usage of a wedge (especially in the height of 2.5 cm) on extremity with high recurvatum angle. Feedback from the participants also showed that with the usage of a 2.5 cm wedge, the feeling of weight on the knees decreased and felt more comfortable. We think that suggesting a 2.5 cm wedge in order to correct the plantar pressure distribution and posture in individuals with GR is a better orthotic treatment approach.

It was hypothesized that the heel wedges used on participants with a normal recurvatum angle would cause mechanical changes in the foot and ankle. It was thought that this situation has positive or negative effects on plantar pressure and posture in healthy individuals. The positive results of wedges in healthy individuals concluded that such therapy could have broader implications, not only as an injury management option, but also as an injury prevention mechanism.[22] Since there are not many studies on GR, we think that this study will contribute to the literature.

The limitations of our study are the evaluation of static pressure and stabilometric analysis parameters by looking at the instant effects of the use of wedges, the lack of dynamic analysis, the lack of long-term effects, and the quadriceps muscle strengthnot being not evaluated. In future studies, it is recommended to examine the long-term effects of insoles use and evaluate the quadriceps femoris muscle strength.

In this study, it was concluded that a 2.5 cm wedge reduces average pressure, maximum pressure, and swing length in both feet. The participants remarked that the feeling of weight on their knees was decreased, and they felt more comfortable when they used a 2.5 cm wedge.

Ethics Committee Approval: Ethical committee approval was approved in the assembly of Istanbul Medipol University Non-Entrepreneurial Clinical Studies Ethical Committee (Date: August 29, 2019, with the case number of 10840098-604.01.01- E.45463 and the resolution number of 633).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – N.H.Y., E.A.; Design – N.H.Y., E.A.; Supervision – E.A.; Funding – N.H.Y., E.A.; Materials – N.H.Y.; Data Collection and/or Processing – N.H.Y., E.A.; Analysis and/or Interpretation – N.H.Y., E.A.; Literature Review N.H.Y.; Writing – N.H.Y., E.A.; Critical Review – E.A.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

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