Effects of Shoe Heel Types on Knee Joint Angle During Gait in Healthy Young Women - A Preliminary Study

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Abstract

This study aimed to determine the effects of different shoe heel types on the knee joint angle during gait. Seven young, healthy women in their 20s participated. Subjects were instructed to choose and walk in their comfortable and fast speed for 2 minutes each on a treadmill while wearing 5 different types of shoes in a random order (flat shoes: 1cm, sneakers: 3cm, high heels: 9cm pump/regular/stiletto design). For motion analysis of the gait, Kinovea was used and the knee joint angles of extension and flexion at heel strike and toe off were compared between the five types of shoes. Results showed that the knee flexion angle at heel strike was significantly decreased in the fast walking speed in all types of shoes ($p<0.05$). During stance phase, knee extension angle was decreased when wearing high heels in fast walking speed. Knee flexion angle during toe-off phase was significantly increased for all shoes in fast walking speed. Wearing stiletto heel was found to increase knee flexion during stance phase and decrease during swing phase during fast gait speed. Findings from this study will provide a basic data for further research in the effects of shoe types on locomotion and prevention for musculoskeletal injuries.

***Keywords*:** Heel height, Shoe design, Gait, Knee joint angle

1. Introduction

Wearing high heels causes changes in balance control and pattern of movement in the lower limb including the kinematics of the hip, knee, ankle joints, and the step length [1]. High heels can lead to musculoskeletal problems such as osteoarthritis, hallucis valgus, and pain [2]. Previous study results stated that increase in heel-height with narrower base altered rate change inclination angle (RCIA) during double leg stance (DBS) and reduced frontal inclination angle (IA) lead to difficulty in maintaining body

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2018R1D1A1B07050037).
This research was also supported by the MSIT (Ministry of Science and ICT), Korea, under the ITRC (Information Technology Research Center) support program (IITP-2019-2014-1-00720) supervised by the IITP (Institute for Information & Communications Technology Planning & Evaluation).

balance and foot stability [3]. The knee and ankle range of motion, increase knee flexion and decrease ankle eversion, were limited by mean of high heel with natural walking speed at initial contact phase of gait [4]. Changes in walking speed and increase in heel height effect on electromyography (EMG) activities of rectus abdominis (RA) and erector spinae muscle (ES) during treadmill walking [5]. In sagittal plane, mean ankle were increased during rearfoot strike compared to forefoot strike running [6], this might cause pain and injury in ankle. Wearing high heels in increased walking speed was noted as a risk factor for knee joint disease and balance control [7].

Scientific studies on the influence of heel heights on variety of factors: rise heel shoes [4], type of high heel [8], shoes size [9], walking speed and narrow shoes base [4,10]. Therefore, wearing high-heeled shoes with natural or modified walking speed can affect foot pressure distribution, balance control, gait pattern, and muscles activities. However, not many studies and evidence define the correlation between different designs of shoes and walking speed. The purpose of this study was to observe the influence of different shoe types on the knee joint angles in two different gait speeds in healthy young females.

2. Methods

2.1 Subjects

To conduct this study, seven young females were recruited. Subject average age was 20.71 years, average weight was 50.43 kg, average height was 157.71 cm and average body mass index (BMI) was 20.32 kg/m^2. Inclusion criteria were as follows: shoes size of 235 mm, has experience in using treadmill, and can wear high heels for running or high-speed walking for 5 minutes. All subjects were healthy without any history of neurologic disorder, cardiovascular disease, musculoskeletal abnormalities, valgus, mild, moderate, severe, high arch foot and flat foot were excluded from participation.

2.2 Shoes

To discover the impact of high heel shoes, five types of shoes were picked such as flat shoes, sneaker, pump heel, stiletto heel and regular heel shoes for this study. All shoes had size of 235 mm, shoes design and their characteristic like heigth, total length, ball width and midfoot length of shoes were showed in Table 1 and Fig. 1.

Table 1. Shoe characteristic (cm)

Shoes	a	b	c	d
Flat	1.0	24.5	8.0	5.5
sneaker	3.0	25.5	9.5	7.0
Pump	9.0	21.5	7.5	5.0
Regular	9.0	25.0	7.5	4.5
Stiletto	9.0	25.0	8.0	5.0

Notes: a) height, b) tota length, c) ball width, d) midfoot length

2.3 Camera and tripod

Range of Motion of knee were detected during trial, so we used smart phone as a camera to video activities while walking on treadmill. To carry the camera, tripod were demanded and set to 1 meter height and 2.5 meter distance from center of treadmill. We marked the position of joints with reflective marker tape at hip, knee and ankle to notify the position clearly. The video were recode with 25 framerate then transfer from phone to computer by USB cable.

2.4 Experiment protocol

All participants were informed the main objective of the study and clearly explained the experiment protocol. The purpose of this study was to compare the effect of flat shoes and sneaker to three different heel-heights at comfortable speed and fast speed walking on treadmill. A seven volunteered healthy women walked on treadmill with random shoes and speed. Ten experiment conditions were designed by mean of flat shoes, sneaker, pump heel, stiletto heel and regular heel at self-select speed and fast speed for two minutes walking and two minutes rest.

2.5 Outcome measurement

Range of motion (ROM) of knee were observed during stance phase like heel strike angle, peak extension, peak flexion and peak flexion at swing phase.

2.6 Data and statistical Analysis

Kinovea 0.8.27, motion analysis software, was used for calibrate the range of motion of knee and MATLAB R2015b was needed for further signal analysis. IBM SPSS Statistic 23 were used for statistical analysis. One way ANOVA were performed to identify the significant difference among group shoes design and paired sample t-test to compare the speed effect.

Fig. 1. Five shoes design and technical meaning of shoes characteristics

Table 2. Result of statistical analysis on knee angle for peak extension, peak flexion and heel strike (SD: standard deviation)

(n=7)

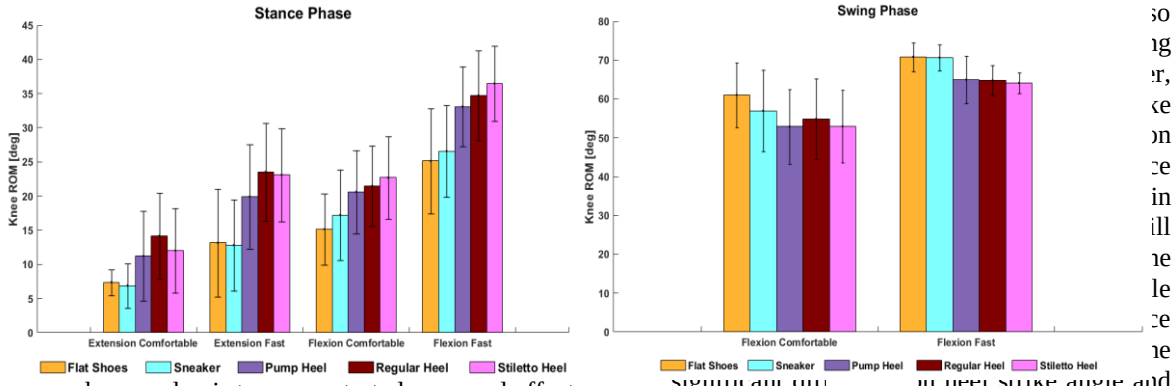
Condition	Shoes	Comfortable		Fast		t (p-value)
		mean	SD	mean	SD	
Heel strike [deg]	Flat	171.53	1.82	164.38	7.99	2.25 (0.066)
	Sneaker	171.64	3.14	164.42	6.69	**3.31 (0.016)**
	Pump	167.69	6.78	157.66	7.32	**4.81 (0.003)**
	Regular	164.72	6.24	153.88	7.12	**6.50 (0.001)**
	Stiletto	166.77	6.34	154.57	6.3	**5.94 (0.001)**
	F (p-value)	2.34 (0.078)		**3.67 (0.015)**		
Extension angle stance phase [deg]	Flat	7.39	1.91	13.16	7.87	- 1.88 (0.110)
	Sneaker	6.91	3.26	12.82	6.69	**- 2.46 (0.049)**
	Pump	11.24	6.6	19.93	7.65	**- 4.74 (0.007)**
	Regular	14.18	6.3	23.55	7.15	**- 5.80 (0.001)**
	Stiletto	12.02	6.2	23.1	6.84	**- 5.53 (0.002)**
	F (p-value)	2.50 (0.064)		**3.64 (0.016)**		
Flexion angle stance phase [deg]	Flat	15.14	5.23	25.13	7.67	**- 2.61 (0.040)**
	Sneaker	17.23	6.59	26.59	6.7	**- 3.75 (0.009)**
	Pump	20.62	6.08	33.11	5.82	**- 4.74 (0.003)**
	Regular	21.48	5.87	34.73	6.56	**- 7.18 (0.000)**
	Stiletto	22.7	6.07	36.47	5.52	**- 6.53 (0.001)**
	F (p-value)	1.94 (0.13)		**4.23 (0.008)**		
Flexion angle swing phase [deg]	Flat	61.02	8.35	70.85	3.69	**- 3.39 (0.015)**
	Sneaker	56.95	10.51	70.64	3.4	**- 4.25 (0.005)**
	Pump	52.89	9.65	64.98	6.05	**- 4.79 (0.003)**
	Regular	54.86	10.32	64.79	3.93	**- 3.07 (0.022)**
	Stiletto	52.93	9.39	64.11	2.63	**- 3.77 (0.009)**

F (p-value)	0.86 (0.497)	**4.72 (0.005)**	

Shoes Type (I)	Shoes Type (J)	Flexion angle stance phase [deg]			Flexion angle swing phase [deg]		
		Mean Difference (I-J)	SD.Error	Sig.	Mean Difference (I-J)	SD.Error	Sig.
Flat	Sneaker	-1.46	3.47	1	0.21	2.19	1
	Pump	-7.98	3.47	0.287	5.87	2.19	0.12
	Regular	-9.6	3.47	0.097	6.05	2.19	0.098
	Stiletto	**-11.34**	**3.47**	**0.027**	**6.74**	**2.19**	**0.045**
Sneaker	Pump	-6.52	3.47	0.702	5.66	2.19	0.15
	Regular	-8.14	3.47	0.259	5.85	2.19	0.122
	Stiletto	-9.88	3.47	0.079	6.54	2.19	0.057
Pump	Regular	-1.62	3.47	1	0.19	2.19	1
	Stiletto	-3.36	3.47	1	0.87	2.19	1
Regular	Stiletto	-1.74	3.47	1	0.69	2.19	1

Table 3. Result of post hoc pairwise comparison of Bonferroni at fast speed (SD: standard deviation)

Fig. 2. Comparison of five type shoes at comfortable and fast walking speed on knee extension and flexion during (A) Stance Phase and (B) Swing Phase



shoes and pair t strated on speed effect for all shoes wit- -icant level of $p < 0.05$. No significant differences on knee extension angle, knee flexion angle, and heel strike angle in stance phase at comfortable speed between so ng r, ce on ce in ill ne le ce ne significant dif in heel strike angle and extension ang detected for sneaker, pump heel, regular heel, and stiletto heel but no found for flat shoes in stance phase due to

speed effect.

To identify which heel-hieght shoes more affected to knee ROM, Bonferroni pairwise of Post hoc were applied to compare each individual shoes at fast speed (Table 3). In post hoc pairwise comparison, in stance and swing phase at high speed walking indicated that knee flexion of stiletto heel differed significantly compare to flat shoes. No significant differences were found on knee flexion in a gait cycle at fast walking speed when compare each heel-height shoes.

Figure 3 demonstrated the comparison of knee ROM for all shoes at each walking speed on treadmill in stance phase and swing phase. Mean knee angle extension were lower and knee flexion were greater in stance phase of height heels versus flat shoes and sneaker. The knee flexion of heel-heights were decreased in swing phase as regards to flat shoes and sneaker.

4. Conclusions

Knee extension, flexion and heel strike are influenced by confounding variable such as heel-heights of 9 cm and fast walking speed. These finding suggest that avoiding fast speed walking or running while wearing heel-height to reduce falling. Moreover, wearing lower heel or sneaker with fast speed walking cause less effect to knee ROM. This study provides information for future studies performed with the aim of preventing and compensating the knee angle effect before and after fast walking using heel-height.

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