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Differences in Gait and Balance as a Result of Wearing 3, 5 and 7 cm Wedge and Non-Wedge Heeled Shoes

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Abstract

Background: High heeled shoes have gained popularity as of late. Wearing such shoes not only results in physical changes to the foot joint and ankle, it also requires the wearer to maintain balance and stability at static as well as dynamic state in order to carry out daily functional activities. There are a few varieties of high heeled shoes with various heights and heel surface areas, such as the wedge and non-wedge style. Differences in heel surface area may result in different physical impacts on the wearer. **Aim:** To present evidence that the use of wedge and non-wedge style shoes at different heights (3, 5 and 7 cm) results in differences in terms of gait and balance. **Method:** Experimental study with pre and post test design. Subjects are women aged 22-24 years old with normal Body Mass Index (BMI). Thirty women who agreed to participate in the study and met the inclusion and exclusion criteria were randomly divided into 3 groups; the 3 cm, 5 cm and 7 cm group, each consisting of 10 subjects. Each group performed walking test to examine gait, one leg stand and tandem stand to examine balance while barefoot, wearing wedge style shoes and wearing non-wedge style shoes with the same height. **Results:** The result of this study indicates significant change in gait and balance between barefoot state and the use of high heeled shoes, both wedge style and non-wedge style (p=0.000). However, there were no significant differences in the impact of wearing 3, 5 and 7 cm wedge shoes on gait (p=0.673) and balance (p=0.200). Insignificant differences in gait (p=0.257) and balance (p=0.961) as a result of wearing non-wedge shoes at the different heights were also found. The difference in gait as a result of wearing wedge and non-wedge was not significant (p=0.111), while the difference in balance as a result of wearing non-wedge and wedge was significant (p=0.000). **Conclusion:** There is difference in balance but not gait as a result of wearing wedge style shoes compared to non-wedge style shoes with different heights (3, 5 and 7 cm).

Keywords: high heeled shoes; wedge; non-wedge; gait; balance.

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1. Introduction

Control of balance is a person's ability to maintain the body's midline against the gravitational line and the swing of the body's center of gravity. Balance is regulated by the central nervous system based on information received by the body's sensory systems such as vision, proprioceptive sensations (muscle movements), and senses such as the vestibular system in the ear. Wearing such shoes not only results in physical changes to the foot joint and ankle, it also requires the wearer to maintain balance and stability at static as well as dynamic state in order to carry out daily functional activities [1]. This happens because the body's compensation for achieving balance, high heels shifts the pedestal of gravity to the front resulting in postural imbalance [2]. These changes reduce the ability to maintain balance during activity and increase the risk of falls and musculoskeletal trauma. The study of spatiotemporal parameters shows the use of high heels can reduce the duration of stance, a phase when the foot touches the ground, length, and angle of the step. The use of high heels increases the risk of falls and musculoskeletal trauma because excessive plantar flexion increases metabolic energy while walking and accelerates muscle fatigue [3]. The inconvenience of wearing high heels is influenced by several factors, including the relation of height of shoes and pressure distribution. Based on the study of Biomechanical Evaluation of Heel Elevation on Load Transfer – Experimental Measurement and Finite Element Analysis of shoe height on foot load distribution to the forefoot is directly proportional [4]. Another factor that affects the discomfort of using high heels is the presence of a contact surface area of shoes. According to a study of plantar pressure distribution shows that the wider the base of the shoe heels, the forefoot pressure is also reduced. High-heeled shoes with narrow heels provide larger plantar pressure, especially on hallux [5].

2. Material and Methods

This study was conducted for two months from November 2018 to December 2018. All procedures were performed in accordance with the Medical Research Ethics Committee Faculty of Medicine University of Prima Indonesia. Thirty samples aged 22-24 years were recruited in this study, all female are medical students with normal Body Mass Index (BMI). Shoe size of 38 to 40 were provided for this study. People with history of trauma and congenital abnormalities that can affect movements of lower extremities were excluded from the study. Informed consent had obtained before research started, as well as measurements of weight and height. Samples were asked to remove their footwear and stamped both their feet in poster paint and walk barefooted on 5-meter-long of paper, this procedure considered as pretest. Step length, stride length, cadence and gait speed were observed on this point. As for parameter of balance, one leg stance and tandem stance, samples were asked to lift one leg alternately for one minute each, with eyes open and closed. The moment when sample fell or can not maintain balance was timed using stopwatch. Tandem stance was observed by putting heel-to-toe position alternately, and timed as well. Samples were grouped randomly to three groups, 10 samples were using 3 cm wedge-styled and non-wedge-styled shoes, 10 samples at 5 cm heeled shoes, 10 at 7 cm heeled shoes. Procedures and parameters were also assessed. All data results were tested for normality test with Shapiro Wilk test, if the data were normally distributed ($p>0.05$), Independent T-test were performed to test the hypothesis. If the data were not normally distributed tests available were Mann-Whitney test for 2-categories data and Kruskal-Wallis test for more than 2 categories data. Data analysis was carried out with IBM SPSS (Statistical Product and Service Solutions) Statistics 22 for Windows software.

3. Result and Discussion

Both parameters gait and balance data are summarized to tables containing average value of three groups.

Table 1: Average gait and balance of pretest and posttest 3 cm wedge and non-wedge heeled shoes

Parameter	Pretest	Posttest	
		Pretest	Posttest
Gait			
Step length	59.20 ± 8.25	52.40 ± 13.56	53.60 ± 6.92
Stride length	114.30 ± 14.54	110.50 ± 17.75	110.50 ± 12.66
Cadence	7.90 ± 1.53	8.10 ± 1.20	8.10 ± 0.99
Gait speed	3.87 ± 1.20	4.63 ± 1.24	4.87 ± 0.86
Balance			
Right foot one leg stance opened eyes	57.65 ± 4.60	50.89 ± 15.58	20.55 ± 14.81
Left foot one leg stance opened eyes	60.00 ± 00.00	53.32 ± 14.77	21.46 ± 18.68
Right foot one leg stance closed eyes	39.87 ± 21.99	17.36 ± 13.34	3.07 ± 0.95
Left foot one leg stance closed eyes	40.43 ± 23.01	10.07 ± 8.16	3.46 ± 1.33
Right foot tandem stance	60.00 ± 00.00	54.19 ± 18.38	51.64 ± 17.98
Left foot tandem stance	60.00 ± 00.00	60.00 ± 00.00	48.73 ± 19.99

Table 2: Average gait and balance of pretest and posttest 5 cm wedge and non-wedge heeled shoes

Parameter	Pretest	Posttest	
		Pretest	Posttest
Gait			
Step length	59.40 ± 7.99	56.50 ± 6.26	51.40 ± 4.43
Stride length	115.50 ± 15.29	111.00 ± 16.59	102.60 ± 0.94
Cadence	7.80 ± 1.40	8.20 ± 1.03	8.70 ± 0.67
Gait speed	3.78 ± 1.14	4.19 ± 0.98	4.13 ± 0.94
Balance			
Right foot one leg stance opened eyes	54.64 ± 11.10	33.45 ± 21.43	22.18 ± 19.33
Left foot one leg stance opened eyes	56.05 ± 12.48	39.96 ± 23.76	22.62 ± 21.75
Right foot one leg stance closed eyes	37.43 ± 21.84	7.72 ± 4.55	9.03 ± 13.60
Left foot one leg stance closed eyes	35.45 ± 22.52	12.50 ± 8.58	4.29 ± 3.61
Right foot tandem stance	60.00 ± 00.00	59.40 ± 1.90	48.31 ± 18.74
Left foot tandem stance	59.83 ± 00.54	53.83 ± 13.69	53.24 ± 14.27

Shapiro Wilk normality test shows the data of gait and balance in both wedge and non-wedge group is not normally distributed. Therefore, hypothetical test used is Kruskal Wallis test with four categories on gait parameter, and six categories on balance parameter.

Table 3: Average gait and balance of pretest and posttest 7 cm wedge and non-wedge heeled shoes

Parameter	Pretest	Posttest	
		Pretest	Posttest
Gait			
Step length	55.60 ± 6.50	54.40 ± 5.36	51.70 ± 9.08
Stride length	111.20 ± 14.04	105.80 ± 11.16	102.10 ± 15.72
Cadence	8.80 ± 1.23	8.90 ± 0.99	8.90 ± 1.10
Gait speed	4.68 ± 10.26	5.15 ± 0.92	5.00 ± 0.90
Balance			
Right foot one leg stance opened eyes	56.76 ± 10.26	52.77 ± 12.26	21.73 ± 21.27
Left foot one leg stance opened eyes	58.82 ± 3.74	54.10 ± 10.10	27.44 ± 23.89
Right foot one leg stance closed eyes	44.01 ± 25.92	16.32 ± 20.82	4.33 ± 3.32
Left foot one leg stance closed eyes	45.60 ± 23.52	11.76 ± 17.09	3.13 ± 1.37
Right foot tandem stance	57.10 ± 9.20	56.92 ± 6.73	54.12 ± 11.08
Left foot tandem stance	60.00 ± 0.00	57.21 ± 8.83	48.53 ± 18.47

Table 4: Gait difference of wedge shoes based on heel height

Gait parameter of wedge shoes	Mean	p
3 cm	43.91	
5 cm	44.97	0.673
7 cm	43.56	

Table 4 shows that the highest mean value of gait in wedge group is the 5-cm-heeled group with 44.97, while lowest mean value is 43.56 by the 7-cm-heeled group with p-value = 0.673 ($p > 0.05$). So that it can be concluded that there is no significant difference of gait between the group of three.

Table 5: Balance difference of wedge shoes based on heel height

Balance parameter of wedge shoes	Mean	p
3 cm	40.97	
5 cm	34.48	0.200
7 cm	41.51	

Table 5 shows that according to heel height, the highest mean value of balance in wedge group is the 7-cm-

heeled group with 41.51, while lowest mean value is 34.48 by the 5-cm-heeled group with p-value = 0.200 (p > 0.05) so it concludes that there is no significant difference of balance between the group of three.

Table 6: Gait difference of non-wedge shoes based on heel height

Gait parameter of non-wedge shoes	Mean	p
3 cm	44.27	
5 cm	41.71	0.257
7 cm	41.93	

Table 6 shows that according to heel height, the highest mean value of gait in non-wedge group is the 3-cm-heeled group with 44.27, while lowest mean value is 41.71 by the 5-cm-heeled group with p-value = 0.257 (p > 0.05) so it concludes that there is no significant difference of gait between the group of three.

Table 7: Balance difference of non-wedge shoes based on heel height

Balance parameter of non-wedge shoes	Mean	p
3 cm	24.82	
5 cm	26.61	0.961
7 cm	26.55	

Table 7 shows that according to heel height, the highest mean value of balance in non-wedge group is the 5-cm-heeled group with 26.61, while lowest mean value is 24.82 by the 3-cm-heeled group with p-value = 0.961 (p > 0.05) so it concludes that there is no significant difference of balance between the group of three.

Table 8: Gait difference on wedge and non-wedge with Wilcoxon Signed Ranks Test

Gait difference	Mean	Z	p-value
Wedge	44.15	-1.594	0.111
Non-Wedge	42.63		

Table 8 shows that the average of gait in wedge group is higher with 44.15, while in non-wedge group is 42.62. Sig-p = 0.111 (p > 0.05) means there is no significant difference of gait between wedge and non-wedge group.

Table 9: Balance difference on wedge and non-wedge with Wilcoxon Signed Ranks Test

Balance difference	Mean	Z	p-value
Wedge	38.99	-3.733	0.000
Non-Wedge	25.99		

Table 9 shows that the average of balance parameter in wedge group is higher with 38.99, while in non-wedge group is 25.99. Sig-p = 0.000 (p < 0.05) means there is significant difference of balance parameter between

wedge and non-wedge group.

Table 10: Pretest and posttest gait difference of wedge and non-wedge with Friedman Test

Gait parameter	Mean	Deviation std.	p
Pretest	46.0030	4.79421	
Posttest Wedge	44.1471	5.46226	0.032
Posttest Non-Wedge	42.6340	4.63742	

Table 10 shows that the average of gait in pretest (barefoot) is 46.00 ± 4.79, while in posttest wedge group is 44.14 ± 5.46, and posttest non-wedge group is 42.63 ± 4.64, means there is significant difference of gait between pretest (barefoot) and posttest wedge and non-wedge group, which are lower than average gait in pretest. Sig $p = 0.032$ ($p < 0.05$).

Table 11: Pretest and posttest balance parameter difference of wedge and non-wedge with Friedman Test

Balance parameter	Mean	Deviation std.	p
Pretest	52.4232	9.14693	
Posttest Wedge	438.9861	8.48361	0.000
Posttest Non-Wedge	25.9925	9.31196	

Table 11 shows that the average of balance parameter in pretest (barefoot) is 52.42 ± 9.15, while in posttest wedge group is 38.98 ± 8.48, and posttest non-wedge group is 25.99 ± 9.31, means there is significant difference of gait between pretest and posttest wedge and non-wedge group, which posttest non-wedge is lower than the average mean in pretest and posttest wedge. Sig $p = 0.000$ ($p < 0.05$). This result of study is slightly similar to previous study by author [6] in Difference in Shape of Wedge and Non-Wedge Shoes towards Gait and Balance which shows significant difference before and after the test. However, the difference in gait parameter between wedge and non-wedge group is not significant and shows various results (step length $p = 0.006$; stride length $p = 0.228$; cadence $p = 0.888$, gait speed $p = 0.679$). While balance parameter difference is not significant between the groups ($p > 0.05$).

4. Conclusion

The result of this study indicates significant change in gait and balance between barefoot state and the use of high heeled shoes, both wedge style and non-wedge style. However, there were no significant differences in the impact of wearing 3, 5 and 7 cm wedge shoes on gait and balance. Insignificant differences in gait and balance as a result of wearing non-wedge shoes at the different heights were also found. The difference in gait as a result of wearing wedge and non-wedge was not significant, while the difference in balance as a result of wearing non-wedge and wedge was significant. There is difference in balance but not gait as a result of wearing wedge style shoes compared to non-wedge style shoes with different heights (3, 5 and 7 cm).

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