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Effects of different heel heights on selected gait parameters of young undergraduate females

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ABSTRACT

The objective of this study was to determine the effects of different heel heights on selected gait parameters in a sample of young Nigerian females. A purposive sample of eighty apparently healthy undergraduates of Nnamdi Azikiwe University, Nnewi Campus participated in the study. Their mean age, height, and weight were 21.98± 1.83 years, 1.65±0.06 meters, 59.50±9.34 kilograms respectively. An ex post facto design was used to investigate the effect of different heel heights (3.2cm, 7.8cm and 11.0cm) on selected gait parameters. This was done using a prepared protocol and measurement of gait parameters were taken with a tape rule and stop watch respectively. One-way ANOVA was used to compare differences across the groups. Level of significance was set at 0.05. There were significant differences in mean values of selected gait parameters across the different heel heights for stride length, step length, stride width, cadence, and velocity respectively. However, with post hoc test, no significant difference exist in mean values between bare foot and low heel of all selected parameters for stride length, step length, and cadence respectively, barefoot and mid heel (p=0.142), and mid and high heel for stride width (p= 0.162) respectively. There was a significant difference exists only between low and high heel on velocity. As heel height increases, gait parameters such as stride length and step length shorten while the cadence increases and the stride width widens. It is recommended that to maintain comfort and reduce the adverse side effects associated with wearing the different heel height, women are advised to minimize putting on heeled shoes particularly the mid and high heels.

Keywords: Gait parameters; Heel height Shoes; Spatial; Temporal.

INTRODUCTION

High heel shoes are a type of footwear typically worn by ladies where the heel of the foot is raised significantly higher than the ball of the foot and the toes [1]. Historically, the use of high heeled shoes is purported to have started during the 14th century when wooden slips called platens were placed on the bottom of footwear to protect them from getting dirty [2]. Ever since then, females across all ages, culture, society and religion have continued to use high heeled shoes. Looking fashionable is the most adjudged reason for the use of high heeled shoes [3]. However, whether it is to gain a height advantage, look professional, or stay with the trend of fashion, it is not entirely uncommon for a female to own numerous pairs of these shoes at one time [4].

For more than 250 years now, the effects of heel height on the wearers' health have become a source of concern [2, 5]. Even though they can be used therapeutically, for instance, in the treatment of tendinitis and partial ruptures of the Achilles tendon [6], their chronic effects as a result of persistent non-prescribed usage has currently become a source of worry to clinicians and scientists alike. A closer subjective look around our environment shows that its usage among females is becoming more common, the heeled shoes are getting higher and its inclines are getting more steeper with toe boxes getting more pointed [7]. This will definitely impact on their pattern of walking, also called gait. The purpose of this present study was to determine the influence of different high heeled heights on the gait parameters of a sample of young females in a Nigerian University Campus. The study therefore sought to answer the following questions:

a. Would different shoe heel heights (barefoot, low, mid and high) affect stride length?
b. Would different shoe heel heights affect step length?
c. Would different shoe heel heights affect stride width?
d. Would different shoe heel heights have effect on the cadence?
e. Would different shoe heel heights have effect on gait speed?

MATERIALS AND METHODS

Research Design

An Ex-Post Facto design was used because the variables used in the study had already occurred and as such the researcher does not have direct control over the variables.

Sample and Sampling Technique

Eighty female participants were recruited from undergraduates of Nnamdi Azikiwe University, Nnewi Campus. This study was delimited to subjects with the following inclusion criteria:

- No known history of musculoskeletal impairment that may restrict the range of lower extremity motion which might make the wearing of shoes painful.
- Subjects that wore only British size 6inches shoes (40cm) because it is the size most ladies use in the environment of the study.
- Experienced wearers of high heeled shoes as evidenced by self reported usage of at least twice a week. This criterion was established to control variation among subjects in their motor control that could result in differences in habitual versus sporadic high shoe wearers.

Research Instruments

- **White Paper –** A length of white paper was placed on the floor for each of the participants to walk on.
- **Shoe Size –** Three British pairs of 6 inches shoe size (40cm) with different heel heights: low heel – 3.3cm, mid heel - 7.8cm and high heel- 11cm were used.
- **Paint –** This was used to stain the heel of each participant.
- **Measuring Tape (Butterfly, USA) –** The type of tape used was the non-elastic tailor tape. It was used to measure the distance in the gait parameters.
- **Stop Watch –** This was used to determine the time for the calculation of gait cadence for each participant.
- **Height Meter (Secca, England) –** This was used to determine the height of the research participant.
- **Weighing Scale (Hanson, Ireland) –** This was used to determine the weight of the research participant.

Procedure for Data Collection

An Ethical approval was sought and obtained from the Ethical Review Committee of Nnamdi Azikiwe University Hospital (NAUTH), Nnewi before commencement of this study. Also informed consent was obtained from each of the participants recruited for the study.

Walk Task

Set up: The participants were first asked to walk bare footed before walking on heeled shoes with different heel heights (low heel, mid heel and high heel) using the protocol described below. A meter strip of masking tape was placed on the paper track at the starting point. 10meter ahead of the starting point, a 2centimeter strip of masking tape was used to mark the end point. A small piece of tape was used to mark the end point so that the subject would not decelerate or accelerate in anticipation of the finish line.

- The researcher explained while demonstrating the walk task to each of the participants; when I say "go" walk at your normal comfortable pace until I say "stop"
- The second research assistant assisted the participants as needed in placing their toes on the starting line tape.
- The researcher would say "go" and the researcher and first research assistant would simultaneously press the stopwatch to begin timing while the second research assistant counted the number of steps.
- The subject walked towards researcher who stood 1m beyond the end point of the 10m distance and the 1st research assistant walked alongside as the subject traversed the 10m distance.
- The researcher and the first research assistant simultaneously pressed their stopwatches to stop at the end of 1 minute. At the same time, the second research assistant would stop counting.
- The number of steps counted by the second research assistant was recorded together

with the average time from the researcher and first research assistant.

- After the walk, the other gait variables were measured with the help of a tape measure following the paint stains on the white paper.

Procedure for Data Analysis

The data for this study was summarized using descriptive statistics of mean and standard deviations. One way Analysis of variance (ANOVA) test and post-hoc test were used to determine differences across and between various gait parameters respectively with alpha level set at $p< 0.05$

RESULTS

Eighty participants were involved in the study. Their age range and mean age were 18-26 years and 21.98±1.83 years respectively. The physical characteristics of the participants on gait are shown in Table 1. ANOVA testing did reveal significant difference on stride length across different heel height ($p = 0.00$), as shown in table 2. ANOVA testing did reveal significant difference on stride width across different heel heights ($p = 0.00$), as shown in table 2. ANOVA testing did reveal significant difference on step length across different heel heights ($p = 0.00$), as shown in table 2. ANOVA testing did reveal significant difference in cadence across different heel heights ($p = 0.00$), as shown in table 2. ANOVA testing did reveal significant difference in velocity across different heel height ($p = 0.01$), as shown in table 2. The gait parameters of participants who wore high heel were different from the bare-foot, low and mid heels ($p < 0.05$), but no significant difference was found between bare-foot and low heel ($p > 0.05$), as shown in table 3. There was no significant difference between the gait parameters of participants who wore bare-foot versus low heel, bare-foot versus mid-heel, high heel versus mid-heel ($p > 0.05$) but others, bare-foot versus high heel, low heel versus mid-heel, low heel versus high heel showed significant difference ($p < 0.05$), as shown in table 3.

The high heel gait parameters were different from bare-foot, low and mid heels ($p < 0.05$) but no significant difference ($p > 0.05$) was found between bare-foot versus low foot gait parameters. No significant difference ($p > 0.05$) was obtained between the gait parameters of those who wore bare-foot versus low heel but bare-foot versus mid-heel, bare-foot versus high heel, low heel versus mid-heel and low heel versus high heel, mid-heel versus high showed a significant difference ($p < 0.05$), as shown in table 3. There was no significant difference between the gait parameters of bare-foot versus low heel, bare-foot versus mid-heel, bare-foot versus high heel, low heel versus mid-heel, and mid-heel versus high heel ($p > 0.05$) but a significant difference between low heel versus high heel ($p < 0.05$), as shown in table 3.

Table 1: Physical Characteristics of the Participants

Variable	Mean± S.D
Age(years)	21.98 ± 1.83
Height(meters)	1.65 ± 0.06
Weight(kilograms)	59.50 ± 9.34

Table 2: Comparison of Gait Characteristics of Participants across Different Heel Heights

Heel Heights	Gait Characteristics				
	Stride length (cm) Mean±S.D	Stride Width (cm) Mean±S.D	Step Length (cm) Mean±S.D	Cadence (steps/min) Mean±S.D	Velocity (cm/s) Mean±S.D
Bare-foot	115.28±13.00	6.09±2.33	57.30±6.30	99.20±12.11	94.00±17.00
Low heel	116.03±12.28	5.74±2.05	57.71±5.85	101.15±4.17	97.44±11.18
Mid-heel	106.45±11.48	6.96±2.57	53.18±6.00	105.06±4.82	93.04±11.84
High heel	99.83±10.65	7.82±2.73	49.78±5.20	109.20±5.19	90.60±11.03
F-value	33.813	11.767	33.075	29.251	3.810
P-value	0.000*	0.000*	0.000*	0.000*	0.010*

*=Significant at 0.05.
S.D = Standard deviation

Table 3: Comparison of different heel heights and gait parameters of participants.
N= Number of participants

Tests	N	Paired Heel heights	Mean± S.D	Mean± S.D	M.D	p-value
Stride Length	80	1&2	115.28±12.96	116.03±12.28	-0.77	1.000
		1&3	115.28±12.96	106.45±11.48	8.83	0.000*
		1&4	115.28±12.96	99.83± 10.65	15.44	0.000*
		2&3	116.03±12.28	106.45±11.48	-9.59	0.000*
		2&4	116.03±12.28	99.83±10.65	16.20	0.000*
		3&4	106.03±11.48	99.83±10.65	-6.61	0.003*
Stride Width	80	1&2	6.09±2.33	5.74± 2.05	0. 35	1.000
		1&3	6.09±2.33	6.96±2.57	-0.88	0.142
		1&4	6.09±2.33	7.82±2.73	-1.73	0.000*
		2&3	5.74±2.33	6.96±2.57	-1.23	0.010*
		2&4	5.74±2.33	7.82±2.73	-2.08	0.000*
		3&4	6.96±2.57	7.82±2.73	-0.86	0.162
Step Length	80	1&2	57.30±6.29	57.71±5.85	-0.40	1.000
		1&3	57.30±6.29	53.18±5.91	4.12	0.000*
		1&4	57.30±6.29	49.78 ±5.20	7.52	0.000*
		2&3	57.71±5.85	53.18±5.91	4.52	0.000*
		2&4	57.71±5.85	49.78±5.20	7.92	0.000*
		3&4	53.18±5.91	49.78±5.20	3.40	0.002*
Cadence	80	1&2	99.20±12.11	101.15±4.17	-1.95	0.557
		1&3	99.20±12.11	105.06±4.82	-5.86	0.000*
		1&4	99.20±12.11	109.19±5.19	-9.99	0.000*
		2&3	101.15± 4.17	105.06±4.82	-3.91	0.005*
		2&4	101.15±4.17	109.19±5.19	-8.04	0.000*
		3&4	105.06±4.82	109.19±5.19	-4.13	0.003*
Velocity	80	1&2	93.95±16.93	97.44±11.18	-3.48	0.544
		1&3	93.95±16.93	93.04±11.84	0.91	1.000
		1&4	93.95±16.93	90.59±11.04	3.36	0.618
		2&3	97.44±11.18	93.04±11.84	4.39	0.198
		2&4	97.44±11.18	90.59±11.04	6.84	0.006*
		3&4	93.04±11.84	90.59±11.04	2.45	1.000

1= Barefoot, 2= Low heel height, 3= Mid heel height, 4= High heel height,
M.D= Mean difference between paired heels S.D= Standard deviation values of each heel height *Significant at 0.05.

DISCUSSION

The primary role of shoes is to protect the foot and facilitate propulsion, however, fashion has strongly influenced the design of footwear throughout the ages, thus, compromising the natural functioning of the foot [8,9]. This study was aimed at determining the effect of different heel heights on gait parameters amongst experienced wearers who are apparently healthy female undergraduates of College of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi campus. The study revealed that as heel height increases, the females display shorter stride length and step length, wider stride width and increase walking cadence. This may be attributed to a more cautious walking pattern so as to compensate for the elevation and forward shift of the centre of gravity, and altered biomechanics of the foot so as to prevent falls and foster postural stability. Godwin et al [10] revealed similar findings in the study of heel heights on gait parameter using five female subjects; and concluded that heel shoes, especially high heeled shoes, causes a decrease in stride length and step length. Gefen et al [11] compared the effect of different heel heights on gait parameters of individuals wearing high heel shoes with low heel shoes or with bare-foot. He noted that individuals on high heeled shoes have shorter stride length and increased walking cadence.

A significant difference in all selected gait parameters across the different heights was observed in the present study. This might be attributed to substantial alteration in the kinematics of the ankle and the knee placing the foot in a more plantar-flexed position at the initiation of support, and an increase in the

centre of gravity as the heel height increases thus shifting the centre of mass forward and resulting in postural instability. This was in agreement with the work of Lee et al [7] who reported that putting on high heel shoes results in alterations of foot biomechanics due to the fact that additional weight are being place on the forefoot; and this, pushes the centre of mass forward placing more stress on the foot impact. With the low and mid heels, the ankle only reached a slightly dorsiflexed position while with the highest heel height, the ankle never attained a dorsiflexed position, thus, the dorsiflexors are not able to act eccentrically through a great range of motion. Knee flexion, on the other hand, increase as a function of increased heel heights throughout the initial shock-absorbing portion of support. Similar findings have been reported by other investigators [12, 13]. Murray et al [12] suggested that increased knee flexion during early support provided the means from moving the centre of mass forward over the larger or more stable foot part of the foot. The difference across the heel height in all the gait parameters can also be attributed to the fact that a standardized new pairs of shoes was used, thus, individuals are not accustomed to walking on the new shoes as compared to when they walk on their own shoes. There was no significant difference between bare-foot versus low heel in all gait parameters of young female undergraduates in this study. This might be attributed to the fact that there might not be alterations in the foot biomechanics and the somatosensory feedback of the foot might still be maintained. This finding is in agreement with Menet et al [14] who noted that there was no significant difference in balance and cadence of individual walking bare-footed and in low heel, but was in contrast with Lord and Bashford [15] study who noted a significant difference in balance and cadence of individuals walking bare footed and in low heel. The contrasting finding was attributed to the kind of population used because an individual not exposed to wearing shoes when placed on low heeled shoes might show alterations in balance [15].

Equally, no significant difference between bare-foot versus mid-heel and mid-heel versus high heel on stride width was found. This might be due to the psychological status which has being opined by Levangie and Norkin [16] as one of the factor that influence gait; because, for the fact that individuals are conscious of being watched it might becloud the actual influence of the different heel height on the gait parameter. It might also be due to the fact that the distance they covered was very short thus; they might tend to maintain their balance within the short distance. It may also be attributed to the type of platform/terrain the individuals walked on. Since the platform was leveled, they might seem to maintain their balance than when they walk on rough and uneven platform.

The study also revealed that significant difference only exist between low heel and high heel on velocity which might be attributed to intra-tester error ; while the rest comparison showed no significant difference which might be due to the fact that the participant used are experienced wearer and thus might be able to walk with constant velocity. Also, the distance and time which the individual walked was short and thus might not alter the velocity. Hence the walking velocity may not be a function of both the cadence and step length in this circumstance. However, a major limitation of this study is that the use of a convenience sample could affect the external validity of the results.

CONCLUSION

This study thus concluded that as heel height increases, certain gait parameters such as stride length and step length shorten while the cadence increases and the stride width widens so as to achieve postural stability and kinematic adaptation. It appeared that wearing heeled shoes changes the orientation of the lower extremity segments with particular changes occurring at the ankle and knee.

RECOMMENDATION

To maintain comfort and reduce risks of injury and other side effects associated with wearing the different heel height, females should be advised to minimize putting on heeled shoes particularly the mid and high heels. Similar studies may also be carried out among elderly women and further studies may consider prospective designs..

REFERENCES

1.Au, E. Y. L & Goonetilleke, R.S. A qualitative study on the comfort and fit of Ladies dress shoes. *Applied ergonomics.*2007, (38); 687-696.

2.Linder, M. & Saltzman,C.L. A history of medical scientist on high heels. *International Journal of Health Service*. 1998, 28(2); 201-225.

3.Franklin Me, Cheiner T C, Braninger L, Cook H & Sheri H. Effect of positive heel inclination on posture. *Journal of Orthopaedic and Sports Physical Therapy*. 1995,21(2):94-99.

4.Henderson P D& Piazza S J: A biomechanical evaluation of standing in high heeled shoes. 2001.www.forms.gradsh.psu.edu. Accessed on 13th November, 2011.

5.Lake N C . High heels and low heels. *Practitioner*. 1949, 163:221.

6.Canale S T& Campbell W C. Campell operative orthopedics. CV Mosby, St Louis. 1998,2:1420

7.Lee, C.M.; Jeong, E.H. & Freivalds, A. "Biomechanical effect of wearing high-heeled Shoes". *International Journal of Industrial Ergonomics*. 2001,(28); 321-326

8.Mcpoil, T.G. Jr. "Footwear". *Physical therapy*. 1988, 68(12); 1857-1865.

9.Coughin, M.J. & Thompson, F.M. "The heel price of high fashioned foot wear". Instr course lecture . 1995, (44); 371 – 77.

10.Godwin, L.; Mckinzie, T. & Royo, M. "The effect of heel height on gait: a kinematic Approach". *Journal of Rehabilitation Research and Development.* 2004, 41(4); 547-554.

11.Gefen, A.; Megido-Ravid, M.; Itzchak, Y. & Arean, M. Analysis of muscular fatigue and foot stability during high-heeled gait. *Gait Posture*. 2002,15(1):56-63.

12.Murray, M.P.; Kory, R.C. & Sepic, S.B. Walking patterns of normal woman. *Archives of Physical Medical Rehabilitation.*1970, (71); 304-307.

13.Opila-correia, K. Kinematics of high heeled gait consideration for age and experience of wear. *Archives of Physical Medical Rehabilitation.* 1990, (71); 905-907

14.Menet, J.C.; Steele, J.R.; Menz, H.B.; Munro, B.J. & Lord, S.R. Effect of footwear feature in balance and stepping in older people. *Gerontology*. 2008, 54(1): 18-23.

15.Lord, S.R. & Bashford, G.M. Shoe characteristics and balance in older women. J.M. *Genatrology society*. 1996,47(6); 681-84.

16.Levangie, P.K. & Norkin, C.C. A comprehensive analysis of joint structure and function

(3rd Edition). 2001,(14); 435-481.