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Characterization of anthropometric parameters, lumbar flexibility and quadriceps angle of adult female users of high-heeled shoes in Calabar, Cross River, Nigeria.

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ABSTRACT

Background: The suitability and health implications of high heel use are essential for users, designers, and health professionals. This study characterized the anthropometric parameters (height, weight, waist-circumference (WC), hip-circumference (HC), body mass index (BMI), and waist-hip ratio (WHR)), lumbar-flexibility (LF) and Quadriceps-angle (Q-angle) of adult female users of high-heeled shoes in Calabar.

Methods: A cross-sectional survey involving 100 adult female users of high-heeled shoes consecutively recruited from banks and the University of Calabar community. Participant's age was obtained, heel-heights, height, weight, WC, HC, BMI, WHR, LF and Q-angle were measured with standard procedures. Descriptive statistics were used to summarize data, and inferential statistics of ANOVA, MANOVA and Pearson's correlation coefficient analyzed data at $p< 0.05$.

Results: Participants' mean age, height, weight, BMI, WC, HC, WHR, Q-angle, and LF were: 26.59±3.34 years, 1.61±0.08 m, 60.24±10.73 Kg, 23.01±3.51 Kg/m², 0.75±0.08m, 0.95±0.12m, 0.79±0.05, 10.30±1.59°, and 0.07±0.03m, respectively. Post-hoc analysis revealed significant difference ($p< 0.05$) between: users of 2- and 3-inches in BMI; 2-inches and 4-inches & above in Q-angle, 3-inches and 4-inches & above in Q-angles, and 2-inches and 4-inches & above in LF. Participants' height, weight, BMI, WC, HC and WHR positively correlated significantly (p<0.05) with heel-heights, whereas LF and Q-angle negatively correlated significantly (p<0.05) with heel-heights.

Conclusion: Adult female users of 3-inches high heels have higher BMI than users of 2-inches, while users of 4-inches & above have lower LF than users of 2-inches. Heel heights are directly related with anthropometric parameters of adult females, but inversely with LF and Q-angle.

Keywords: Anthropometric parameters, High-heeled shoes, Lumbar flexibility, Quadriceps angle, Cross River, Nigeria

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INTRODUCTION

High-heeled shoes are distinctive forms of footwear characterized by elevated heels than the toes.[1, 2] They are available in various styles, including pumps, stilettos, block, wedges, platforms, kitten and sculptural.[3, 4] Heel height varies considerably, ranging from a few centimeters to several inches, with features of pointed or rounded toe designs.[4-6]Specifically, high heels are defined as "shoes in which the heel is higher than the forepart.[7]"High-heeled shoes are categorized based on heel heights into low, medium, high, and ultra-high, with each category exerting distinct effects on comfort, balance, and biomechanical function.[2, 4 ,6, 7] The aesthetic and functional diversity of heel types serves various preferences and social contexts.[3, 6] The suitability and health implications of high heels are essential for users, designers, and health professionals, as it informs their evolution, modification and usage and highlights the social, cultural and health relevance.[3, 6]

The variations in heights of heels reflect the influence of evolving fashion trends, cultural norms, and technological advancements.[3] Low heels which range from 1 to 2 inches provide minimal elevation while maintaining postural stability and comfort.[3, 4, 8] Medium heels which measures about 3 to 4 inches, represent a balance between aesthetic appeal and functional comfort.[3, 8] In contrast, high heels, often defined as those exceeding 4 inches, are symbolic of femininity, sophistication, and elegance.[3, 4]Stiletto heels are associated with altered gait mechanics, reduced postural stability, and a higher risk of falls due to the need for continuous postural adjustments.[1, 3] While platform heels may offer more uniform pressure distribution than stilettos, they do not eliminate the biomechanical risks associated with high-heeled footwear.[1, 3]Both stiletto and platform heels pose significant challenges with prolonged use, contributing to discomfort and increased injury susceptibility.[1, 3, 7]

High heels alter lower extremity biomechanics, shifting body weight towards the forefoot due to forced plantarflexion.[1, 9-11] This increases pressure on the metatarsal heads, raising the risk of forefoot pain and long-term musculoskeletal issues.[1, 10] High heels also affect gait, kinematics, and kinetics, contributing to conditions like hallux valgus and musculoskeletal injuries.[7, 12] They change body balance, centre of pressure, and plantar pressure distribution,[1, 6] often affecting comfort and posture. Prolonged use is linked to low back pain, knee osteoarthritis, and foot and ankle pain.[11] Regular use of heels over 2 inches can cause calf muscle and Achilles tendon changes, leading to stiffness and shortening.[1]A study found that high-heeled shoe users with heel heights of about 2 inches had an increased Q-angle compared to those wearing regular heels.[13]Sharma and Borka noted significant differences in Q-angle between users of 0 and 3-inch heels.[14] Also, higher heels is related with increased Q-angle in normal heels users.[15] Although other factors influencing lower extremity biomechanics may affect Q-angle changes.[1] Regarding lumbar lordosis, conflicting studies exist. Cronin's review reports some studies show decreased lumbar lordosis with higher heels, while others found no change or an increase.[16] Lumbar lordosis, when exaggerated (hyperlordosis) or reduced (hypolordosis), is associated with pain, disability, and limited lumbar flexibility.[17] Increased heel height has been associated with decreased lumbar flexion,[9] and frequent high-heel use can alter lumbar curvature, contributing to back pain.[15, 16]

However, there appear to be limited studies on the anthropometric variables, LF and Q-angle of adult female high heel users based on heel heights. The literature showed correlations exist among heel height, BMI, and postural balance,[18] as well as among height, weight, and BMI and Q-angle.[19]These associations have not been explored in adult females using varying heel heights. Therefore, this study characterized the height, weight, BMI, waist circumference (WC), hip circumference (HC), WHR, LF and Q-angle of adult female high-heel users in Calabar, Nigeria. It was hypothesized that these variables would not be significantly different across heel heights.

METHODOLOGY

This study employed a cross-sectional survey design and consecutivelyrecruited100 consenting adult female participants who used high-heeled shoes from banks in Calabar (Zenith International Bank, United Bank for Africa, Globus Bank, and Guaranty Trust Bank) and the University of Calabar community. Inclusion criteria were adult females aged 18 years and above who were habitual users of high-heeled shoes (defined as heels of 2 inches or higher) for at least one year and demonstrate right lower extremity dominance. Participants were excluded if they had: any congenital disorder in the lower extremity, pre-existing musculoskeletal conditions or

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foot pain that limited the use of high-heeled shoes in the last one year, and pregnancy.

Ethical approval was obtained from the Health Research Ethics Committee of the Ministry of Health, Cross River State (CRS/MH/HREC/024/Vol.V1/522). Thereafter, the researcher visited various banks in Calabar Metropolis to seek permission to conduct the study. Only four banks as listed above granted permission to conduct the study within their premises and informed their heads of operations and relevant stakeholders about the study. Also, the researcher obtained permission from the head of students' halls of residence and residential quarters of the University of Calabar. Verbal consent was obtained from each participant after a full explanation of the study's objectives, procedures, potential risks or benefits, researchers' affiliations, and assurance of voluntary participation without repercussions.

Following the approval and permissions, visits were conducted at the various bank's locations, students' halls of residence and staff residential quarters of the University of Calabar. Eligible participants were scheduled for data collection. The researcher visited each location with a portable plinth and collected participants' age, heel heights, height, weight, WC, HC, LF and Q-angle.

Measurement of heel heights: A tape measure (Stanley® PowerLock® Tape Measure, United States) was used to measure heel heights to the nearest 0.1 inches. Participants were asked to present their regularly used high-heeled shoes. The researcher measured the back of the heel from the bottom to the point where it connects the sole of the shoe.

Measurement of anthropometric parameters: Participants' heights were measured with a height meter to the nearest 0.1m. Participants were instructed to stand erect by the wall with their backs against the wall and feet together. Then the researcher placed a meter rule on the participants' vertex and took reading from the height meter. Also, participants' weights were measured with a standard weighing scale to the nearest 0.1Kg. The participants were asked to be on light shorts and stand on the weighing scale with head erect. Then the researchers read the weights from the scale and recorded it. The BMI of each participant was calculated as the ratio of their weight to the square of their heights in Kg/m^2. The tape measure (Stanley® PowerLock® Tape Measure, United States) was used to measure WC and HC of the participants according to the procedure described by the world health organization.[20] Participants were asked to stand erect with light clothes and feet close together, arms at the side and body weight evenly distributed. Then the researcher measured the WC midpoint between the lower margin of the least palpable rib and the top of the iliac crest. To measure participants HC, the tape rule was placed round the greatest prominence of the hip, and the measurement of the HC was read to the nearest 0.1m. Participant's WHR was calculated by dividing the WC by the HC to the nearest one decimal place. For both the WC and HC, the participants were instructed to be relaxed, and the measurements were taken at the end of a normal expiration.

Measurement of Quadriceps angle: Participants' Q-angle for the right knee was measured with the circle universal manual goniometer (Baseline® 180 Degree Economy Plastic) using the procedure described by Weiss et al.[21]Participants lay supine on a plinth with knees extended, and the researcher beside the plinth. The hips, knees and feet of the participant were placed in a neutral position. The researcher then identified and labeled the anterior superior iliac spine (ASIS), mid-point of the patella and the tibia tubercle. A line was thereafter drawn from ASIS to the midpoint of patella and then from the midpoint of the patella to the tibia tubercle. The angle formed by the crossing of the two lines was measured and recorded as the Q-angle (Figure 1). Surface goniometry for the measurement of Q-angle is reported to be reliable.[21]

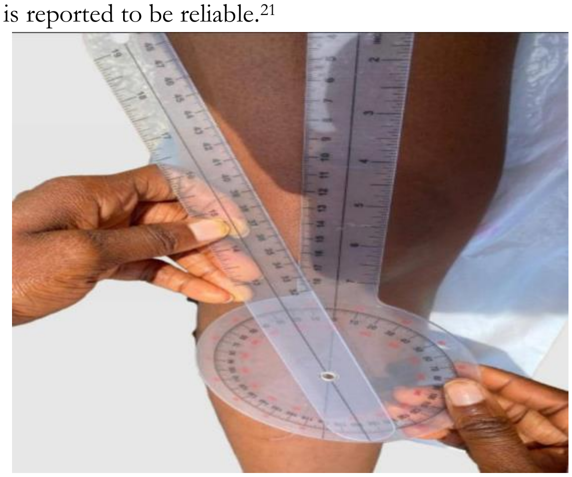

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Figure 1: Measurement Quadriceps angle with a universal circle goniometre

Measurement of lumbar flexibility: The modified Schober's procedure described by Meritt et al. was used to measure LF.[22] Participants were asked to stand upright on bare feet with their trunk exposed. The researcher marked a spot at the spinous process of the L4 vertebral, indicated by a horizontal line connecting the participants' posterior superior iliac spine. Another spot was marked at 5 cm below the first spot. A third spot was marked at 10cm above the first spot. The participants were instructed to bend forward to touch their toes (Figure 2). The researcher re-measured the distance between the third and second spots with the participants fully flexed and subtracted 15cm from it to obtain the LF values of participants. The obtained values of LF were recorded to the nearest 0.1m.

Estimation of Participants Sedentariness: The time participants spent in sitting or lying with no physical activity was evaluated using an equation derived with a multiple linear regression model from the National Health and Nutrition Examination Survey Data (NHANES) 2017-2018 data,[23] with age, BMI, and WC as predictor variables. The equation used was: Sedentary Time (minutes/day) = 200 + (9 × BMI) + (0.5 × WC) − (1.5 × Age). This provided a modeled approximation of daily sedentary time of the participants.

Data analysis: Data were analyzed using IBM SPSS Statistics, version 26. Descriptive statistics of mean, standard deviation, frequency and percentages were used to summarize data on participants' age, heel heights, height, weight, BMI, WC, HC, WHR, ST, LF and Q-angle. Levene's test of equality of error variances was used to assess the assumption of homogeneity of variances among the dependent variables. One-way analysis of variance (ANOVA) was used to compare participants' height, weight, BMI, WC, HC, WHR, ST, LF and Q-angle across heel heights. A multivariate analysis of variance (MANOVA) was performed using Pillai's Trace as the multivariate test statistics to examine the effect of heel heights on participants' BMI, WHR, LF and Q-angle. Due to unequal number of participants across heel heights, a post hoc analysis was conducted using the Dunnett's T3correction to control for Type I error in multiple comparisons. Pearson's correlation coefficient was used to determine the relationship between participants' heel heights and variables of age, height, weight, BMI, WC, HC, WHR, ST, LF and Q-angle. The level of statistical significance was set at $p < 0.05$.

RESULTS

Participants' physical characteristics are presented in Table 1. The mean age of the participants was 26.59±3.34years. The mean height, weight and BMI of the participants were 1.61±0.08m, 60.24±10.73Kg and 23.01±3.51Kg/m^2, respectively. The mean WC, HC and WHR of the participants were 0.75±0.08m, 0.95±0.12m and 0.79±0.05, respectively. Also, the mean Q-angle was10.30±1.59˚ with 25 percentile at 9.00˚ and 75 percentile at 11.00˚, while the mean LF was 0.07±0.03m with 25 percentile at 0.05m and 75 percentile at 0.09m.

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Table 1: Physical characteristics of all participants (N=100)

Variables	Mean ± SD	Minimum	25%	50%	75%	Maximum
Age (years)	26.59 ± 3.34	20.00	24.24	26.00	29.00	37.00
H-Heels (inches)	2.78 ± 0.81	2.00	2.00	2.00	3.00	5.00
Height (m)	1.61 ± 0.08	1.17	1.56	1.58	1.66	1.80
Weight (Kg)	60.24 ± 10.73	38.20	53.10	55.15	65.00	108.00
BMI (Kg/m2)	23.01 ± 3.51	16.75	20.76	21.92	25.00	44.37
WC (m)	0.75 ± 0.08	0.63	0.70	0.71	0.79	0.97
HC (m)	0.95 ± 0.12	0.19	0.89	0.93	1.01	1.35
WHR	0.79 ± 0.05	0.69	0.75	0.77	0.82	0.92
Q-angle (°)	10.30 ± 1.59	7.00	9.00	11.00	11.00	15.00
LF (m)	0.07 ± 0.03	0.02	0.05	0.08	0.09	0.11
ST (Min/day)	404.85 ± 34.54	335.21	666.33	381.93	399.24	422.97

Keys: BMI= Body mass index, WC= Waist circumference, HC= Hip circumference, WHR= Waist to hip ratio, Q-angle= Quadriceps angle, ST= Sedentary time, H-Heels= Height of high-heels, Min=Minutes.

This study revealed that participants' who use higher high heels have higher mean height, weight, WC and HC than those who use lower high heels (Table 2). Participants who wear high heels of 4-inches & above were averagely overweight and had higher WHR compared to participants who wear high heels of 2 and 3 inches, respectively (Table 2). On the other hand, participants who wear high heels of 4- inches and more had lower Q-angles and LF compared to participants who wear high heels of 2 and 3 inches, respectively (Table 2).

Table 2: Anthropometric, lumbar flexibility and quadriceps angle profiles of adult female users of high heels

Variables	Mean ± SD	Minimum	25%	50%	75%	Maximum
H-Heels (2 inches) (n=40)						
Age (years)	26.85 ± 3.34	20.00	24.00	26.00	29.00	37.00
Height (m)	1.59 ± 0.05	1.51	1.54	1.58	1.63	1.66
Weight (Kg)	54.94 ± 6.79	30.17	38.20	55.15	59.20	78.90
BMI (Kg/m2)	21.76 ± 2.35	16.75	20.00	21.92	22.67	29.00
WC (m)	0.71 ± 0.06	0.63	0.68	0.71	0.74	0.91
HC (m)	0.92 ± 0.08	0.71	0.88	0.93	0.97	1.18
WHR	0.78 ± 0.04	0.72	0.75	0.77	0.79	0.92
Q-angle (°)	10.43 ± 1.43	8.00	9.00	11.00	11.00	15.00
LF (m)	0.08 ± 0.02	0.03	0.06	0.08	0.09	0.11
ST (Min/day)	391.31 ± 22.10	339.75	379.34	392.82	401.18	463.00
H-Heels (3 inches) (n=45)						
Age (years)	26.78 ± 3.13	20.00	25.00	27.00	29.00	36.00
Height (m)	1.62 ± 0.09	1.17	1.58	1.62	1.68	1.74
Weight (Kg)	62.01 ± 8.55	49.00	55.30	59.00	68.05	83.00
BMI (Kg/m2)	23.46 ± 2.71	17.19	21.43	23.55	25.39	30.24
WC (m)	0.77 ± 0.08	0.68	0.70	0.75	0.82	0.94
HC (m)	0.96 ± 0.15	0.19	0.90	0.97	1.03	1.17
WHR	0.79 ± 0.06	0.69	0.74	0.78	0.83	0.92
Q-angle (°)	10.58 ± 1.60	7.00	10.00	11.00	12.00	15.00
LF (m)	0.07 ± 0.03	0.02	0.05	0.07	0.09	0.11
ST (Min/day)	409.34 ± 26.68	335.21	390.52	411.40	430.24	467.66
H-Heels (4-inches&above)						
Age (years)	25.33 ± 2.97	20.00	24.00	26.00	27.00	30.00
Height (m)	1.66 ± 0.08	1.54	1.59	1.67	1.71	1.80
Weight (Kg)	69.10 ± 16.80	49.40	55.20	64.00	80.00	108.00
BMI (Kg/m2)	25.04 ± 6.27	19.10	21.00	23.48	27.86	44.37

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WC (m)	0.81 ± 0.09	0.72	0.73	0.79	0.86	0.97
HC (m)	1.02 ± 0.12	0.87	0.95	1.01	1.09	1.35
WHR	0.79 ± 0.04	0.71	0.76	0.80	0.81	0.86
Q-angle (°)	9.13 ± 1.51	7.00	8.00	10.00	10.00	11.00
LF (m)	0.06 ± 0.02	0.03	0.03	0.06	0.08	0.10
ST (Min/day)	427.74 ± 60.40	371.90	393.00	408.82	453.24	616.33

Keys: BMI= Body mass index, WC= Waist circumference, HC= Hip circumference, WHR= Waist to hip ratio, Q-angle= Quadriceps angle, ST= Sedentary time, H-Heels= Height of high-heels, Min=Minutes.

Participants' variables of weight, BMI, WC and WHR were statistically significant ($p < 0.05$) and hence not homogenous, while variables of Q-angle and LF were homogenous (Table 3).

Table 3: Baseline comparison of physical characteristics of participants based on heel heights using Levene test of homogeneity

Variables	Levene statistics	df1	df2	p-value
Age (years)	0.41	2	97	0.666
Height (m)	1.42	2	97	0.246
Weight (Kg)	16.05	2	97	0.000***
BMI (Kg/m2)	7.96	2	97	0.001***
WC (m)	4.78	2	97	0.011***
HC (m)	2.08	2	97	0.131
WHR	4.16	2	97	0.018***
Q-angle (°)	0.34	2	97	0.716
LF (m)	2.23	2	97	0.113

Keys: BMI= Body mass index, WC= Waist circumference, HC= Hip circumference, WHR= Waist to hip ratio, Q-angle= Quadriceps angle, LF= Lumbar flexibility, ST=Sedentary time, ***= significant at $p < 0.05$.

Participants with higher high heels were statistically significantly ($p<0.05$) higher in height, weight, WC, and HC than participants with lower high heels (Table 4). On the other hand, participants with higher high heels were statistically significantly ($p<0.05$) lower in Q-angle and LF than users of lower high heels (Table 4).

Table 4: One-way ANOVA among participants measured anthropometrics, lumbar flexibility and quadriceps angle

Variable	Sum of Squares	df	Mean Sum of Squares	F-ratio	p-value
Height	0.05	2	0.03	4.57	0.013***
Weight	2443.69	2	1221.83	13.23	0.000***
WC	1148.68	2	574.34	11.54	0.000***
HC	1266.29	2	633.14	4.47	0.014***
Q-angle	24.51	2	12.26	5.30	0.007***
LF	44.37	2	22.18	3.69	0.029***

Keys: WC= Waist circumference, HC= Hip circumference, Q-angle= Quadriceps angle, LF= Lumbar flexibility, ***= significant at $p < 0.05$

However, a statistically significant MANOVA effect was revealed for heel heights (Pillai's Trace=0.338, F=3.15, p=0.003) indicating statistically significant difference in participants parameters of BMI (p=0.004), Q-angle (0.007), and LF (0.029) (Table 5).

Table 5: A multivariate analysis of effect of heights of high heels on participants' anthropometrics, lumbar flexibility and quadriceps angle

Source	Dependent Variables	Type 111 Sum of Squares	df	Mean Square	F	p-value	Partial Etta Squared
H-Heels	Age	27.98	2	13.99	1.26	0.288	0.025
	BMI	134.11	2	67.05	5.97	0.004**	0.110
	WHR	0.004	2	0.00	0.92	0.401	0.019

Q-angle	24.51	2	12.26	5.30	0.007***	0.098
LF	24.51	2	22.18	3.69	0.029***	0.071

Keys: BMI= Body mass index, WHR= Waist to hip ratio, Q-angle= Quadriceps angle, LF= Lumbar flexibility, STSedentary time, H-Heels= Height of high-heels, ***= p is significant.

Additionally, the post-hoc analysis revealed statistically significant difference (p=0.008) in BMI between users of 2- and 3-inches high heels (Table 6). Similarly, statistically significant difference (p=0.025) in Q-angle was found between users of 2-inches and 4-inches & above high heels, and between users of 3-inches and 4-inches& above high heels (p=0.012) (Table 6). Users of 2-inches and 4-inches & above high heels were significantly different (p=0.023) in LF (Table 6).

Table 6: Dunnett's T3 pairwise comparison between heights of high-heeled shoes for dependent variables of body mass index, lumbar flexibility and quadriceps angle

Dependent Variable	(I)H-Heels	(J)H-Heels	MD(I-J)	SE	p-value	95% Confidence Interval	
						Lower Bound	Upper Bound
BMI (Kg/m2)							
	2	3	-1.70	0.55	0.008**	-3.04	-0.36
		4	-3.29	1.66	0.177	-7.71	1.12
	3	4	-1.59	1.67	0.718	-6.02	2.84
Q-angle (°)							
	2	3	-0.15	0.33	0.954	0.95	0.65
		4	1.29	0.45	0.025***	0.14	2.44
	3	4	1.44	0.46	0.012***	0.28	2.61
LF (m)							
	2	3	0.78	0.53	0.372	-0.51	2.08
		4	1.98	0.68	0.023***	0.23	3.73
	3	4	1.20	0.72	0.277	-0.61	3.01

Keys: BMI= Body mass index, Q-angle= Quadriceps angle, LF= Lumbar flexibility, ST-Sedentary time, H-Heels= Height of high-heels, ***= p is significant.

There was a weak significant correlation between participants' high heels and each of height (r=0.29, p=0.003) and HC (r=0.29, p=0.004), whereas a moderate significant correlation was found between participants' high heels and each of weight (r=0.46, p=0.000), BMI (r=0.33, p=0.001), WC (r=0.44, p=0.000), and ST (r=0.37, p=0.000) (Table 7). On the other hand, a weak but negative significant correlation was found between participants' high heels and each of Q-angle (r=-0.20, p=0.042) and LF (r=-0.26, p=0.008) (Table 7).

Table 7: Relationship between heel heights and variables of age, anthropometric, lumbar flexibility and quadriceps angle of all participants

Variable	r	p-value
Age * heel heights	-0.13	0.211
Height * heel heights	0.29	0.003***
Weight * heel heights	0.46	0.000***
BMI * heel heights	0.33	0.001***
Waist circumference * heel heights	0.44	0.000***
Hip circumference * heel heights	0.29	0.004***
Waist-to-height ratio * heel heights	0.13	0.204
Quadriceps angle * heel heights	-0.20	0.042***
Lumbar flexibility * heel heights	-0.26	0.008***
Sedentary time * heel heights	0.37	0.000***

Key: BMI=Body Mass Index, *=Significant relationship**

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DISCUSSION

This study characterized the height, weight, WC, HC, BMI, WHR, LF and Q-angle of adult female users of high-heeled shoes in Calabar, Nigeria. The mean participants' age of 26 years observed in this study is comparable to the 25 years reported in a systematic review and meta-analysis by Zeng et al,[1] which explored the effects of high-heeled shoes on lower limb biomechanics and balance in females. According to Schröder, "the biomechanical adaptations to high heel use vary by age group: women aged 18 to 34 tend to use higher heels and compensate for increased heel heights by flattening lumbar lordosis, while older women at 50 to 79 years of age compensate with increase in thoracic kyphosis".[24]

Participants in this study have normal mean values of BMI and WHR; although, participants differ across heel heights in anthropometric characteristics of height, weight, WC and HC, respectively. Participants' who used shoes with 4-inches & above high heels were overweight. The mean values of participants' WC and HC reported in this study were higher than the means of age-specific values of WC and HC reported among female population in Lagos, Nigeria.[25]Variations in mean values of WC across studies are reported to be influenced by age, ethnicity, and gender.[25, 26] Okafor et al. reported average WC and HC values of 0.79 m and 0.91 m, respectively, in a Nigerian population with a mean age of 39 years.[26] While the mean of 0.75m observed in this study for WC aligns with the findings of Okafor et al, the mean of HC reported in this study is higher than the finding of 0.91m for HC. This discrepancy may be attributed to demographic differences, as the present study's participants were younger (under 30 years of age) and were habitual users of high-heeled shoes, in contrast to the participants in Okafor et al. who were not identified as users of high-heeled shoes.

Additionally, this study found that participants wearing 3-inch heels were significantly heavier than those wearing 2-inch heels. Similarly, a positive relationship was observed between heel heights and participants' weight, BMI, WC, and HC. These findings suggest that higher heels are associated with greater anthropometric values. These findings are buttressed by the finding of this study that the estimated sedentary time increased with heel heights. The findings of this study align with the finding of Kanwal et al,[27] who reported body composition differences among female high-heel users and noted lower physical activity levels in those wearing higher heels. Physical inactivity and higher BMI are linked to increased sedentary time,[28] and inactivity is a known risk factor for obesity and related health issues.[29]However, socio-cultural, physiological, and biomechanical factors may also influence heel height choices. Wade and colleagues reported that high heels enhance perceived attractiveness, femininity, and body contours,[30] possibly explaining why women with higher BMI and WC may prefer higher heels to enhance their physical appearance.

In particular, the finding of this study indicates that the mean Q-angle of all participants was substantially lower than the established normative range for adult Nigerian females. Omololu et al. reported a Q-angle range of 21–28° in adult Nigerian females with a mean age of 22 years,[31] while Jaiyesimi and Jegede documented a range of 14–17° for a similar demographic.[32] In contrast, this present study found a considerably lower mean Q-angle of 10.30° among participants with a slightly older mean age of 26 years, which on the other hand is consistent with the report of Jaiyesimi and Jegede of a mean right knee Q-angle of 10.38˚ among male participants.[32] It is important to note that unlike the aforementioned Nigerian studies, this present study was focused on habitual users of high-heeled shoes. A possible explanation could be long-term neuromuscular adaptations or compensatory changes in the pelvic or hip posture among habitual wearers of high-heeled shoes. Furthermore, this study found that Q-angles decreased with higher heel heights, confirming an inverse relationship between heel height and Q-angle.[33] Taller individuals tend to have lower Q-angles,[32, 34] explaining the capacity of higher heels to induce similar influence. However, this contradicts the report of Khasawneh et al. who alleged that taller individuals generally have greater Q-angles due to factors like pelvic width and femoral alignment.[35] Lower Q-angle have been found to be associated with stronger quadriceps, while a higher Q-angle indicates weaker muscles.[34, 36] The effect of high heels on quadriceps strength may depend on usage duration, as prolonged wear leads to muscle fatigue, while short-term use strengthens the quadriceps.[36] High-heel wearers typically limit usage to prevent discomfort. However, abnormal Q-angles are linked to knee problems such as osteoarthritis and

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patellofemoral pain.[34] Therefore, the reduced Q-angle from high heel use may impact long-term knee health, suggesting the need for longitudinal studies on heel heights and Q-angle in habitual users of high heels.

Finally, this study found that users of heels 4-inches & above had lower LF than those using 2-inch heels, consistent with previous studies that trunk angles decrease with higher heel heights.[9, 21] Decrease in LF suggests a loss of lumbar lordosis, which is linked to reduced lumbar spine flexibility.[21] While LF for 2-inch and 3-inch users was within normal limits measured by the modified Schober's test,[37] 4-inch & above users had LF values 0.01m below the normal mean, indicating reduced LF. This may predispose users to lumbar spine flattening. Drzał-Grabiec and Snela found similar reductions in lumbar lordosis in 10cm (about 4-inch) heel users, compared to 4cm (2-inch) users and barefooters.[38] Flattening of the lumbar spine can reduce load-bearing capacity, leading to overload and pain,[38] and reduced LF is a known risk factor for low back pain.[39]

Based on the findings of this study, it is recommended that adult females limit high-heeled shoe use to 2 inches or less to reduce the risk of physical inactivity and loss of lumbar lordosis. Regular stretching and strengthening exercises should be encouraged for frequent high-heel users to counteract negative effects on anthropometric indices and lower limb function. Healthcare professionals, fashion influencers, and media should raise awareness of the long-term health risks of high-heeled shoes. Educational campaigns should inform women about the biomechanical effects of high heels, helping them make more informed footwear choices. Orthopedic evaluations and gait analyses can also assist in selecting shoes that suit individual anatomical and functional needs, reducing discomfort and preventing musculoskeletal damage.

CONCLUSION

This study found that participants who use 4-inches & above high heels were overweight, while participants who use 2-inches and 3-inches high heels had normal weight. However, adult female users of 3-inches high heels had higher BMI than users of 2-inches, while users of 4-inches & above have lower LF than users of 2-inches. Heel heights were directly related with height, weight, BMI, WC, HC and WHR, but inversely with LF and Q-angle of adult females.

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