INSIGHTS-JOURNAL OF
HEALTH AND REHABILITATION

IMPACT OF DIFFERENT HEEL HEIGHTS ON STEP LENGTH AND STRIDE LENGTH OF UNDERGRADUATE STUDENTS OF LAHORE MEDICAL AND DENTAL COLLEGE

Original Research

Ifrah Suhail[1]*, Suffain Khalid[2], Mir Shakeel Ahmad[3], M. Hamd Ali[2], Farhan Javaid Awan[1], Abida Wahab[4]
[1]Physical Therapist, Ghurki Trust and Teaching Hospital,Lahore, Punjab, Pakistan.
[2]Senior Physical Therapist, Ghurki Trust and Teaching Hospital,Lahore, Punjab, Pakistan.
[3]Clinical Supervisor, Ghurki Trust and Teaching hospital, Lahore, Punjab, Pakistan.
[4]Senior Physical therapist, Pakistan.
Corresponding Author: Ifrah Suhail, Physical Therapist, Ghurki Trust and Teaching Hospital,Lahore, Punjab, Pakistan, Ifrahs08@gmail.com
Acknowledgement: The authors express sincere gratitude to all participants and institutional staff for their valuable support during this study.

Conflict of Interest: None Grant Support & Financial Support: None

ABSTRACT

Background: High-heeled footwear has become a defining element in modern fashion, often worn without consideration for its biomechanical consequences. Among these, alterations in gait patterns—specifically step length and stride length—are notable concerns. Prolonged use of elevated heels may influence musculoskeletal alignment and walking mechanics. Evaluating how different heel heights affect these spatial parameters of gait is crucial for understanding their clinical and functional implications.

Objective: To evaluate the impact of varying heel heights on step length and stride length among undergraduate female students at Lahore Medical and Dental College.

Methods: A descriptive cross-sectional study was conducted over six months, involving 100 healthy female participants aged 19–25 years, selected through non-probability convenience sampling. Shoe sizes 6–8 (UK/PAK) were used across four heel heights: flat (0.2 inches), low (1.5 inches), medium (2.5 inches), and high (3.2 inches). Step and stride lengths were recorded using an observational gait analysis (OGA) system, involving inked footprints on a 20-foot white paper walkway. Measurements were taken with ABN measuring tape. Mean values for physical characteristics were: age 22.97 ± 1.20 years, height 5.38 ± 0.23 ft, weight 126.10 ± 21.46 lbs, and BMI 21.87 ± 3.99. One-way ANOVA was used for statistical analysis, with significance set at $p<0.05$.

Results: Statistically significant differences were observed in step length across heel heights (p=0.000), while no significant difference was noted in stride length (p=0.487). Post-hoc paired comparisons confirmed significant step length variations between all heel combinations.

Conclusion: The study concludes that increasing heel height leads to a consistent increase in step length, while stride length remains largely unaffected. These findings underscore the biomechanical impact of footwear on gait dynamics.

Keywords: Gait analysis, Heel height, Kinematic analysis, Kinetic analysis, OGA system, Step length, Stride length.

INTRODUCTION

Gait, defined as the pattern or manner of walking, plays a pivotal role in daily human mobility and postural stability. While often conflated with locomotion, gait refers more specifically to the rhythmic and coordinated movement of limbs that allows for forward progression, characterized by a biphasic shifting of the center of gravity with minimal energy expenditure (1). Understanding gait is fundamental not only in the study of normal biomechanics but also in the clinical evaluation of pathological conditions. The gait cycle comprises two primary phases: the stance phase, constituting approximately 62% of the cycle where the foot remains in contact with the ground, and the swing phase, covering the remaining 38%, during which the foot is airborne (2). Within this cycle, two distinct periods exist. Double limb support, which comprises about 40% of the cycle, occurs when both feet are in contact with the ground. It includes initial double limb stance, where weight is transferred to the leading limb, and terminal double limb stance, where the weight shifts from the trailing to the leading limb. The second period, single limb support, makes up 60% of the cycle and involves one foot bearing the entire body weight as the other limb transitions forward (3). Analyzing these phases offers critical insights into neuromuscular coordination and lower limb functionality, particularly in clinical rehabilitation settings. Gait analysis, a systematic approach to studying walking patterns, is divided into two major components: kinetic and kinematic analysis. Kinetic gait analysis involves the study of forces and torques generated during movement, particularly focusing on ground reaction forces measured by force plates using strain gauge or piezoelectric technologies. These forces are vital in evaluating load distribution and joint stress, especially in patients with impaired gait mechanics. In healthy individuals, pressure points remain consistent during ambulation, whereas pathological gait patterns can cause abnormal pressure distribution, leading to secondary musculoskeletal issues (4).

On the other hand, kinematic analysis focuses on the movement of body segments relative to each other. It can be further subdivided into quantitative and qualitative analysis. Quantitative gait analysis uses spatial and temporal parameters such as step length, stride length, step time, stride time, swing time, cadence, and velocity. These variables are influenced by intrinsic factors such as age, gender, weight, and physical activity levels (5). Meanwhile, qualitative gait analysis relies on observational methods to assess joint displacement and movement patterns, using systems like the Traditional Gait Analysis and the Rancho Los Amigos Observational Gait Analysis (OGA). The latter is globally favored for its systematic evaluation of each joint segment through the stance and swing phases (6,7). Despite its subjective nature, the OGA has demonstrated high intra-rater reliability (0.86) and overall consistency (0.94), making it a valuable tool in clinical diagnostics and treatment monitoring (8). The advent of observational gait analysis requires adherence to specific protocols, including proper camera positioning, choice of body segment, movement plane selection, and precise identification of gait cycle phases. Such structured methods allow clinicians to pinpoint deviations in normal gait patterns, estimate joint angles, and evaluate treatment effectiveness (8). Furthermore, deviations in gait mechanics are not merely of clinical concern but also have socio-cultural underpinnings. One pertinent example is the prolonged use of high-heeled footwear among women, a practice with historical roots dating back to the 14th century. Initially designed to protect footwear, elevated soles evolved into symbols of social status, confidence, and professionalism (9). However, the aesthetic benefits of heel usage are offset by biomechanical consequences. Prolonged heel wear has been linked to spinal misalignment, altered lumbar lordosis, plantar fasciitis, ligamentous strain, and structural deformities such as hammer toe and crooked foot, thereby underscoring the need for greater awareness regarding footwear-related gait alterations (10). Despite extensive documentation of the basic mechanics and clinical significance of gait, there remains a notable gap in literature concerning the long-term impact of habitual high heel use on gait dynamics. Understanding how footwear influences gait is crucial for developing preventive and rehabilitative strategies, especially for populations at risk of musculoskeletal disorders. The objective of the present study is to investigate the influence of varying heel heights on gait parameters and to explore the potential biomechanical and clinical implications associated with prolonged use of high-heeled footwear.

METHODS

This descriptive cross-sectional study was conducted over a six-month period from July 2020 to December 2020 at Lahore Medical and Dental College. The primary aim was to investigate the influence of varying heel heights on gait parameters among female undergraduate students. Participants were selected through a non-probability convenient sampling technique. The sample size was determined using Taro Yamane's formula: $n = N / (1 + N(e)^2)$ (Yamane, 1967), where N represents the population (300) and e is the margin of error (0.1).

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

The calculated sample size was 100. Participants included healthy female undergraduate students aged 19 to 25 years with a shoe size between 6 and 8 (UK/PAK), intact sensory, motor, and cognitive function, and prior experience wearing high-heeled shoes to ensure natural walking patterns during assessment. Students with any history of recent lower extremity surgery, unresolved leg length discrepancy, spinal deformities (e.g., scoliosis), recent ankle injuries, musculoskeletal pain, restricted lower limb range of motion, or abnormal gait were excluded to avoid confounding variables (11). Following approval from the Ethical Review Committee of Lahore College of Physical Therapy, Lahore Medical and Dental College, and after obtaining informed written consent, data collection commenced. Body weight was measured using a ZT-160 weighing scale and converted into pounds where necessary, while height was measured in feet using a standard measuring tape. These values were used to calculate BMI, which was categorized using WHO criteria: underweight (<18.5), normal (18.5–24.9), overweight (25–29.9), and obese (>30).

To assess gait parameters, a 20-foot-long white paper strip was placed on the floor, and ink or paint was applied to the soles of each participant's shoes to leave visible footprints. Participants first walked for one minute in each condition to normalize their gait and avoid conscious alterations. Gait was evaluated across four standardized heel heights: flat (0.2 inches), low (1.5 inches), medium (2.5 inches), and high (3.2 inches). All four heel heights were tested for each shoe size, correcting a prior discrepancy in reporting. The step length and stride length were then measured using an ABN measuring tape and non-elastic therapeutic tape for consistency. Each participant completed the walking task across all four heel heights, and measurements were recorded by a trained assistant to ensure objectivity. All data were analyzed using SPSS software. Descriptive statistics including frequencies, means, and standard deviations were computed for age, height, weight, BMI, and gait parameters under each heel condition. To assess statistical differences in step length and stride length across heel heights, one-way analysis of variance (ANOVA) was performed, with a significance level set at $p < 0.05$. All ethical considerations were rigorously followed, ensuring confidentiality, voluntary participation, and adherence to research ethics throughout the study.

RESULTS

A total of 100 female participants were enrolled in the study to evaluate the effect of heel height on gait parameters. The mean age of participants was 22.97 ± 1.20 years. The average body mass index (BMI) was 21.87 ± 3.99, falling within the normal BMI range. The mean weight of participants was recorded as 126.10 lbs (±21.46), and the mean height was 5.38 ± 0.23 feet. Gait characteristics were assessed across four different heel heights: flat (0.2 inches), low (1.5 inches), medium (2.5 inches), and high (3.2 inches). For flat shoes, the mean first step length was 1.04 ± 14.75 cm, the second step length was 1.02 ± 14.70 cm, and the stride length was 1.01 ± 15.44 cm. In low heels, the mean first step length was 52.25 ± 8.27 cm, the second step length was 51.91 ± 7.69 cm, and the stride length was 1.04 ± 14.75 cm. With medium heels, the first step length averaged 50.34 ± 8.99 cm, second step length 51.44 ± 7.42 cm, and stride length 1.02 ± 14.70 cm. For high heels, the first step length was 50.59 ± 8.24 cm, second step length 50.81 ± 9.56 cm, and stride length 1.01 ± 15.44 cm. One-way ANOVA revealed statistically significant differences in first and second step lengths across different heel heights (p = 0.000), while no significant difference was observed in stride length (p = 0.487). Further post-hoc comparisons between paired heel heights showed significant mean differences in step length and stride length between nearly all pairs of heel types (p = 0.000). These findings indicate that heel height distinctly affects the step length in female gait, whereas stride length remains relatively unaffected.

Table 1: Descriptive Statistics of Participants' Physical Characteristics

Variables	Minimum	Maximum	Mean	Std. Deviation
Age	20.00	25.00	22.97	1.20
Weight in lb	77.16	176.37	1.2610	21.464
Height in ft	4.90	5.90	5.3760	0.227
BMI	14.20	33.60	21.8740	3.9967

Table 2: Gait Parameters Across Different Heel Heights

Heel Height	Gait Variable	Minimum (cm)	Maximum (cm)	Mean (cm)	Standard Deviation (cm)
Flat (0.2 in)	1st Step Length	77.00	135.00	1.04	14.75
	2nd Step Length	56.00	150.00	1.02	14.70
	Stride Length	57.00	133.00	1.01	15.44
Low Heel (1.5 in)	1st Step Length	37.00	70.00	52.25	8.27
	2nd Step Length	38.00	69.00	51.91	7.69
	Stride Length	77.00	135.00	1.04	14.75
Medium Heel (2.5 in)	1st Step Length	22.00	92.00	50.34	8.99
	2nd Step Length	34.00	69.00	51.44	7.42
	Stride Length	56.00	150.00	1.02	14.70
High Heel (3.2 in)	1st Step Length	22.00	72.00	50.59	8.24
	2nd Step Length	23.00	77.00	50.81	9.56
	Stride Length	57.00	133.00	1.01	15.44

Table 3: One-Way ANOVA Results for Gait Parameters Across Heel Heights

Heel height	1st step length	2nd step length	Stride length
F- value	648.662	602.408	.813
P- value	.000	.000	.487

Table 4: Post-Hoc Paired Comparisons of Gait Parameters Across Heel Heights

Gait Parameter	N	Paired Heels	Mean ± SD (Heel A)	Mean ± SD (Heel B)	Mean Difference (MD)	P-value
Stride Length	100	1 & 2	1.0140 ± 15.44	1.0413 ± 14.75	-0.0273	.000
		1 & 3	1.0140 ± 15.44	1.0178 ± 14.70	-0.0038	.000
		1 & 4	1.0140 ± 15.44	1.0140 ± 15.44	0.0000	.000
		2 & 3	1.0413 ± 14.75	1.0178 ± 14.70	0.0235	.000
		2 & 4	1.0413 ± 14.75	1.0140 ± 15.44	0.0273	.000
		3 & 4	1.0178 ± 14.70	1.0140 ± 15.44	0.0038	.000
2nd Step Length	100	1 & 2	1.0178 ± 14.70	51.9100 ± 7.69	-50.89	.000
		1 & 3	1.0178 ± 14.70	51.4400 ± 7.42	-50.42	.000
		1 & 4	1.0178 ± 14.70	50.8100 ± 9.56	-49.79	.000
		2 & 3	51.9100 ± 7.69	51.4400 ± 7.42	0.47	.000
		2 & 4	51.9100 ± 7.69	50.8100 ± 9.56	1.10	.000
		3 & 4	51.4400 ± 7.42	50.8100 ± 9.56	0.63	.000
1st Step Length	100	1 & 2	1.0413 ± 14.75	52.2500 ± 8.27	-51.21	.000

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

Gait Parameter	N	Paired Heels	Mean ± SD (Heel A)	Mean ± SD (Heel B)	Mean Difference (MD)	P-value
		1 & 3	1.0413 ± 14.75	50.3400 ± 8.99	-49.30	.000
		1 & 4	1.0413 ± 14.75	50.5900 ± 8.24	-49.55	.000
		2 & 3	52.2500 ± 8.27	50.3400 ± 8.99	1.91	.000
		2 & 4	52.2500 ± 8.27	50.5900 ± 8.24	1.66	.000
		3 & 4	50.3400 ± 8.99	50.5900 ± 8.24	-0.25	.000

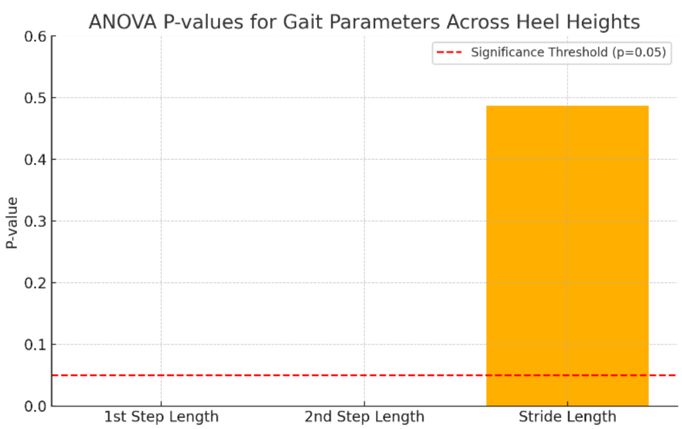

Figure 1 ANOVA P-values for Gait Parameters Across Heel Heights

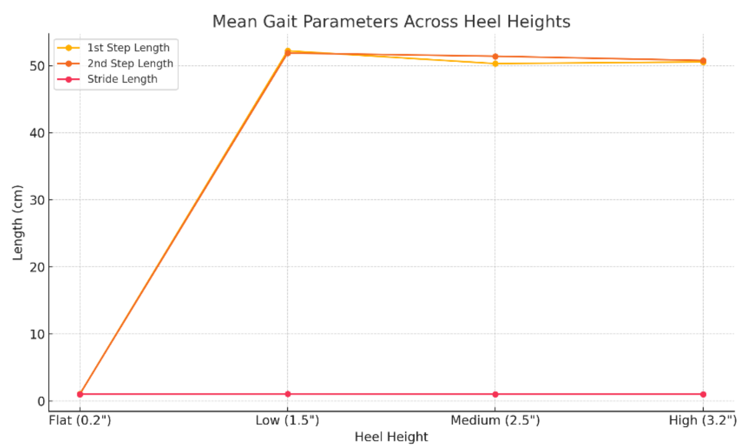

Figure 2 Mean Gait Parameters Across Heel Heights

DISCUSSION

Footwear has long been an integral component of global fashion, yet its biomechanical implications, particularly in relation to heel height, warrant significant clinical attention. The findings of this study revealed that as heel height increased, a statistically significant change occurred in each step length of the gait cycle, while overall stride length remained unaffected. These results align with existing literature that demonstrates alterations in gait patterns associated with high-heeled footwear, including reduced step length, increased foot external rotation (out-toeing), and limited range of motion in the subtalar joint, all of which contribute to biomechanical deviations during locomotion (12,13). Additionally, prior studies have demonstrated that high heels can increase compressive forces on the patellofemoral joint, potentially leading to degenerative changes that further influence gait (14). The present study supports these observations, particularly in its analysis of step length variations across flat, low, medium, and high heel conditions. A unique aspect of this research lies in the pairing of heel heights for comparative analysis, which offered robust insight into the linear relationship between heel elevation and alterations in step mechanics (15). However, unlike several earlier studies that utilized stilettos or pump heels, this investigation employed block heels, which are biomechanically more stable. This distinction may partially explain variations in stride uniformity despite measurable differences in step length. This research focused on undergraduate physical therapy students—a population that inherently maintains prolonged standing postures due to the demands of their academic and clinical routines. The selection of this specific group allowed for a controlled evaluation of heel-induced gait modifications in individuals likely accustomed to some degree of biomechanical strain (16,17). Nevertheless, it must be acknowledged that habitual heel wearers and occasional users exhibit differing adaptations in gait patterns, suggesting the need for broader sampling across various professions to generalize findings effectively.

The absence of participants with musculoskeletal impairments or leg length discrepancies served as a strength, ensuring homogeneity in baseline biomechanics (18,19). Furthermore, by eliminating the use of prosthetic or orthotic devices, the study aimed to isolate the impact of heel height on otherwise healthy gait. Despite this methodological consistency, the reliance on manual observational techniques—specifically ink footprint analysis and tape measurements—posed a limitation. Though efforts were made to minimize human error by assigning a single evaluator, the absence of digital gait analysis systems, such as force transducers or motion capture technology, may have introduced measurement variability and reduced the sensitivity to detect subtle biomechanical changes (20,21). The use of high-precision devices in previous literature has enabled detailed evaluations of vertical ground reaction forces and joint kinetics, supporting the development of rehabilitation protocols based on objective data. This study, while observational, laid foundational insight for such future applications. However, incorporating digital tools such as pressure-sensitive mats, wearable sensors, and 3D motion analysis in subsequent studies could enhance reliability, eliminate potential observational bias, and provide dynamic real-time analysis of joint kinematics and loading patterns.

Another limitation was the relatively narrow heel height range and shoe size variation. While all participants fell within the shoe size range of 6 to 8 (UK/PAK), the diversity in foot morphology and structural alignment may still have influenced the results. Furthermore, external factors such as surface type, walking speed, and prior footwear habits were not controlled, which could confound the relationship between heel height and gait adaptation. In conclusion, the study contributed valuable evidence demonstrating that increased heel height alters step length significantly, supporting prior biomechanical findings while introducing additional data through heel pairing comparison. Despite methodological limitations, the study offers a foundation for future research aiming to explore long-term consequences of high heel use across different populations and occupational backgrounds. Further investigations utilizing technologically advanced gait analysis systems and expanded participant diversity are essential to deepen understanding and to guide preventive and rehabilitative strategies for musculoskeletal health in women.

CONCLUSION

This study concluded that increasing heel height leads to noticeable changes in step length, highlighting its impact on gait mechanics. While step length consistently altered across flat, low, medium, and high heel conditions, stride length remained largely unaffected. These findings underscore the biomechanical influence of elevated heels on spatial gait parameters, particularly in healthy young adults. The study contributes meaningful insight into how variations in footwear, specifically heel height, can affect walking patterns—information that holds practical value for clinicians, physical therapists, and individuals who wear heels regularly.

AUTHOR CONTRIBUTION

Author	Contribution
Ifrah Suhail*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Suffain Khalid	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Mir Shakeel Ahmad	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
M. Hamd Ali	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Farhan Javaid Awan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Abida Wahab	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

REFERENCES

1. Cho YJ, Lee DW, Shin HS, Hwang YB, Lee DO, Kim DY, et al. Change of In-Shoe Plantar Pressure According to Types of Shoes (Flat Shoes, Running Shoes, and High Heels). Clin Orthop Surg. 2022;14(2):281-8.
2. Lee S, Xu M, Wang L, Li JX. Effect of High-Heeled Shoes on Balance and Lower-Extremity Biomechanics During Walking in Experienced and Novice High-Heeled Shoe Wearers. J Am Podiatr Med Assoc. 2020;110(4).
3. Yawar A, Lieberman DE. Effects of shoe heel height on ankle dynamics in running. Sci Rep. 2024;14(1):17959.
4. Major MJ, Quinlan J, Hansen AH, Russell Esposito E. Effects of women's footwear on the mechanical function of heel-height accommodating prosthetic feet. PLoS One. 2022;17(1):e0262910.
5. Gamez-Paya J, Dueñas L, Arnal-Gómez A, Benítez-Martínez JC. Foot and Lower Limb Clinical and Structural Changes in Overuse Injured Recreational Runners Using Floating Heel Shoes: Preliminary Results of a Randomised Control Trial. Sensors (Basel). 2021;21(23).
6. Abe D, Tashiro T, Motoyama K, Horiuchi M, Saito A. Gait variability of interlimb coordination in high-heeled shoes with detachable base sockets under conditions of sinusoidal speed change. Gait Posture. 2023;106:80-5.
7. Beck ON, Schroeder JN, Sawicki GS. Habitually wearing high heels may improve user walking economy in any footwear. J Appl Physiol (1985). 2024;136(3):567-72.
8. Pino-Ortega J, Oliva-Lozano JM, Gómez-Carmona CD, Rojas-Valverde D, Bastida-Castillo A, Moreno-Pérez V, et al. Impact of high-heeled and sport shoes on multi-joint external load profile during walking. J Back Musculoskelet Rehabil. 2021;34(3):389-98.
9. Shang J, Chen L, Zhang S, Zhang C, Huang J, Wang X, et al. Influence of high-heeled shoe parameters on biomechanical performance of young female adults during stair ascent motion. Gait Posture. 2020;81:159-65.
10. Ishii Y, Date K, Itami T, Yoneyama J, Matsui N, Shinoda N, et al. Shoe-Type Walking Assist Device with Controllable Subtalar Joint Alignment at Heel Contact. IEEE Int Conf Rehabil Robot. 2023;2023:1-6.
11. Massoud R. A type-2 fuzzy index to assess high heeled gait deviations using spatial-temporal parameters. Comput Methods Biomech Biomed Engin. 2022;25(2):193-203.
12. Takata Y, Uchiyama E, Kimura K, Arikushi K, Ikeno H, Matamura T. Wearing high-heeled shoes on a side slope makes standing balance unstable. J Bodyw Mov Ther. 2023;33:171-5.
13. Hamandi, S. J. and D. M. Ruken (2020). Biomechanical study with kinematic and kinetic descriptions of the effect of high-heeled shoes in healthy adult females based on gait analysis. IOP Conference Series: Materials Science and Engineering, IOP Publishing.
14. Inam, S. (2020). "A Analysis of Basic Spatial Gait Parameters in Laboratory." Sukkur IBA Journal of Emerging Technologies 2(2): 7-12.
15. Cha, Y.-J. (2020). "Analysis of Differences in the Degree of Biomechanical Adaptation according to Habituation to Different Heel Heights." The Scientific World Journal 2020.
16. Gimunová, M., M. Zvonař, et al. (2020). "Special footwear designed for pregnant women and its effect on kinematic gait parameters during pregnancy and postpartum period." PloS one 15(5): e0232901.
17. Cha, Y.-J. (2020). "Analysis of Differences in the Degree of Biomechanical Adaptation according to Habituation to Different Heel Heights." The Scientific World Journal 2020.
18. Gimunová, M., M. Zvonař, et al. (2020). "Special footwear designed for pregnant women and its effect on kinematic gait parameters during pregnancy and postpartum period." PloS one 15(5): e0232901.
19. Hamandi, S. J. and D. M. Ruken (2020). Biomechanical study with kinematic and kinetic descriptions of the effect of high-heeled shoes in healthy adult females based on gait analysis. IOP Conference Series: Materials Science and Engineering, IOP Publishing.
20. Inam, S. (2020). "A Analysis of Basic Spatial Gait Parameters in Laboratory." Sukkur IBA Journal of Emerging Technologies 2(2): 7-12.
21. Shang, J., X. Geng, et al. (2020). "Influences of high-heeled shoe parameters on gait cycle, center of pressure trajectory, and plantar pressure in young females during treadmill walking." Journal of Orthopaedic Surgery 28(2): 2309499020921978

