International Journal of Health Sciences and Research
Vol.14; Issue: 1; January 2024
Website: www.ijhsr.org
Original Research Article *ISSN: 2249-9571*

The Effect of Heel Height on Balance, Lumbar Lordosis and Core Muscle Strength among Young Healthy Indian Females

Gayatri Joshi[1], Himanshu Pathak[2], Vijaya Bagade[3], Shweta Naidu[4]

[1]Assistant Professor, Department of Musculoskeletal Physiotherapy, Saicare Physiotherapy College, Nashik, India
[2]Professor and Head, Department of Musculoskeletal Physiotherapy, CMF's College of Physiotherapy, Chinchwad, Pune, India
[3]Professor, Department of Musculoskeletal Physiotherapy, St. Andrews College of Physiotherapy, Pune, India
[4]Professor, Department of Musculoskeletal Physiotherapy, Dhole Patil College of Physiotherapy, Pune, India

Corresponding Author: Gayatri Joshi

DOI: https://doi.org/10.52403/ijhsr.20240117

ABSTRACT

Background: High heels are commonly used by young females on daily basis. Increase in heel height cause shortening of calf muscles which affects body's dynamic balance. Anterior tilting of pelvis leads to increase in lumbar lordosis which exert stress on muscles around lumbar spine and weakness of core muscles. In the present study, an attempt has been made to compare the high heel users with flat footwear users to find the effects on balance, lumbar lordosis and core muscle strength.
Methodology: Fifty subjects fulfilling the inclusion and exclusion criteria were randomly allocated into two groups: High heel users (group A) and Flat footwear users (group B).
Assessment of dynamic balance was done by using Modified Star Excursion Test (m SEBT) or Y balance test. Lumbar lordosis angle was assessed by flexible ruler method. Core muscle strength was assessed by Sahrmann Core Stability Test.
Results: The results of the present study showed that mean values of dynamic balance, lumbar lordosis and core muscle strength in both groups are statistically significant. It indicated that dynamic balance, lumbar lordotic angle and core muscle strength are affected more in group A than in group B.
Conclusion: This study concludes that there is significant effect of heel height on dynamic balance, lumbar lordosis and core muscle strength in women who regularly wear high heeled footwear which can be correlated to increased episodes of lower lumbar pain, imbalanced gait and postural problems.

Keywords: Dynamic balance, Lumbar lordosis, Core muscle strength

INTRODUCTION

High heeled shoes are considered as fashionable and are used commonly by females on a daily basis. Literature suggests about by 39% to 69% of women use them on a daily basis with 10% using them for more than 8 hours each day.[1] This footwear provides a raised heel support, raising the foot above the level of toes, increasing the apparent height of the wearer. On the contrary, flat footwear is considered as a symbol of beauty and is thought to be more comfortable providing classical elegance. Flat footwear covers greater area on forefoot than hindfoot.[2] In individuals wearing high heeled shoes usually present with ankle plantar-flexion, compensatory knee flexion and anterior tilting of the pelvis in an effort to stand upright,that can cause increase in lumbar lordosis.[3] Use of raised heeled shoes has been thought to alter the centre of gravity of the wearer. The centre of gravity

(COG) of the human body is a hypothetical point situated anterior to the second sacral vertebra in anatomical position and changes with change in body posture.[4] Thus it has been shown that an increase of 3 inch of heel height shifts the COG to a new level at Lumbar 5th vertebra causing immediate changes in alignment of vertebral column causing the body to compensate for balancing and standing upright. Moreover, the change in COG affects loading of bodyweight on the foot.[5] Habitual wearing of high heeled shoes may lead to abnormal postural alignment leading to calf muscle and Achilles tendon shortening. Plantar flexion of the foot leads to shortening of calf muscle tendon unit which causes increase in actin-myosin overlap and forces muscle fibers into non optimal operating range. With increasing heel height, there is incremental flexion at knee resulting in shortness of hamstrings which limits full knee extension. Increase in stiffness of tendo-achilles tendon, reduced ankle ranges and tightness of lower limb muscles can affect balance. Because of tightness of these muscles, compressive forces act on lumbar spine which might be precipitated as back pain after use of high heeled shoes. [6-8]

High heels lead to forward lean of the body which is compensated by hyperlordotic posture of the spine which puts excessive pressure on nerve endings around lumbar spine which causes low back pain.[9] Chronic use of high heeled shoes is known to cause fatigue of lumbar muscles, due to which most women complain of low back pain.[10] Studies have proved that lumbar lordotic angle (LLA) was increased in low back pain.[6]

Lumbar lordosis is the ventral curvature of the spine which is formed by the lumbar vertebrae and intervertebral discs. It is considered as a key component in maintaining sagittal balance of the vertebral column. Abnormal lumbar curvature can disturb the balance in standing.[11] The normal value of LLA can be defined as 20-45 degrees with a range of 1 SD.[12]

Many women wear high heeled shoes when they are outside. Daily activities such as standing, walking, stair climbing put greater demand on body when high heeled shoes are used. Standing or walking in high heeled shoes, not only cause change in the position of foot and ankle joints, lower extremity, but also impairs the dynamic balance of the body.[13]

Dynamic balance is measured by Y balance test which is also called as Modified Star Excursion Balance Test. Y balance test is the simplified version of Star Excursion Balance Test (SEBT). It is also widely used for pre and post rehabilitation performance measurements, fitness programs and return to sport readiness.[14]

Core muscle strength is necessary for maintaining body's balance which may be disturbed on wearing high heels. Core stability is important for maintaining proper posture of lumbar and pelvic regions during dynamic activities. Core muscle strength is assessed by using Sahrmann Core Stability Test. [15] Anterior pelvic tilt is caused by tightness of iliopsoas and rectus femoris muscles along with tightness of erector spinae.[16] In addition, excessive anterior pelvic tilt has been linked to decrease in core muscle strength. Weakness of core muscles is associated with the anatomical position of the female pelvis and the function of the core muscles, which in turn causes increase in anterior pelvic tilt and low back pain. Standing in high heeled shoes can alter the length of the core muscles which can further affect the normal lordotic angle. [17,18]

Many literatures have shown direct association between balance and core muscle strength. Also, effects of high heeled shoes on balance and lumbar lordosis are still inconclusive. In this study we aim to study the effect of all these parameters on core muscle strength which is optimal for maintaining dynamic balance when high heeled shoes are used on regular basis.

MATERIALS & METHODS

Fifty female subjects were selected to participate in this cross-sectional study and were divided in two groups A and B. The study included subjects who were nulliparous females between age group of 18 to 25 years, with normal BMI range (18.5 to 24.9) wearing high heel footwear (2 to 4 inches) and those wearing flat heel footwear (less than 0.5 inches) for an average time period of 5 hours per day, minimum 4 times a week since 2 to 5 years (Avg 3.5 years) (Table 1).

Inclusion Criteria	**Exclusion Criteria**
Subjects wearing block-heel of 2 inches to 4 inches	Subjects with lower limb injuries,
Age group 18 years to 25 years	Chronic lower back pain
Nulliparous women	Neurological conditions
BMI within normal range	pathology of Spine, hip, knee or foot

Table 1:Inclusion and Exclusion Criterias

They were conveniently sampled in two groups of 25 participants each. Twenty-five subjects who used to wear high heeled footwear (heel height of 2-4 inches) were groups together in group A and those wearing flat heeled footwear (less than 0.5 inches) were grouped in group B. Any subjects with lower limb injuries or any pathology of spine, hip, knee, foot or any neurological deficits were excluded from the study. Subjects who were involved in any type of core strengthening activities or exercises were excluded from the study. Multiple parameters were evaluated. Modified star excursion balance test or Y balance test was conducted to evaluate dynamic balance and a balance score was calculated.

1) Modified Star Excursion Balance Test or Y balance test [1]

Subjects were asked to stand, in the middle of the testing grid with high heeled shoe on. The grid consisted of 3 lines at angle of 120 degrees from each other. Subject were asked to stand on their dominant limb and were asked to touch their non stance limb by keeping hands on hip, to the most distal portion on the lines as much as she can do, in the following directions- Anterior, posteromedial, posterolateral. Subjects were asked to return non stance extremity back to the center while maintaining the balance of the other extremity. Three successful repetitions were performed in each direction with rest of minimum 15 seconds

In between trials to avoid fatigue. Average of reach distance in each direction was normalized to limb length using following formula:

Balance score= Mean reach distance ÷ apparent limb length × 100

2) Measurement of lumbar lordosis [11]

Lumbar lordosis was calculated using a 30 cm flexible ruler method. Flexible ruler was placed between L1 and S2 with subjects in relaxed standing position.

L1 and S2 points were marked. Flexible ruler was placed firmly between L1 and S2 to eliminate gap between the ruler and skin. Markings on the ruler corresponding to the curve were noted. The curve was traced onto the paper for further analysis. A line (L) was drawn between two points (A and B), corresponding to the L1 andS2 markings of the curve. Another line (H) will be drawn perpendicular to line L, which represented height of the height of the lumbar curve.

These two measurements (L and H) were recorded from the ruler (in cms) Angle theta (θ) was measured by using these measurements in the equation:

$$\theta = 4\arctan\left(\frac{2H}{L}\right)$$

Angle theta (Ɵ) represented degree of lumbar lordotic curve.

3) Core muscle strength by Sahrmann Core Stability Test [19]

Core muscle strength was recorded by using Sahrmann Core Stability Test. Aneroid sphygmomanometer was used in this test. The Sahrmann core stabilizing test requires subject to lie in supine position with the knees flexed and feet flat on the mat. Inflatable pressure cuff of Aneroid sphygmomanometer was placed under the lower back of the subject.

Inflatable cuff was inflated to a pressure of 40mm Hg. Subjects were asked to activate deep abdominal muscles by performing "drawing in" technique. This technique was taught to subjects at the beginning of the test and subjects were given trials to avoid errors during the test.

The subjects were asked to perform series of leg lifting exercises given in Sahrmann core stability test table. (figure 1)

Sahrmann Core Stability Test	
Level 1	Begin in supine, crook-lying position while abdominal hollowing Slowly raise 1 leg to 100° of hip flexion with comfortable knee flexion Opposite leg brought up to same position*
Level 2	From hip-flexed position, slowly lower 1 leg until heel contacts ground Slide out leg to fully extend the knee Return to starting flexed position
Level 3	From hip-flexed position, slowly lower 1 leg until heel is 12 cm above ground Slide out leg to fully extend the knee Return to starting flexed position
Level 4	From hip-flexed position, slowly lower both legs until heel contacts ground Slide out legs to fully extend the knees Return to starting flexed position
Level 5	From hip-flexed position, slowly lower both legs until heels 12 cm above ground Slide out legs to fully extend the knees Return to starting flexed position
* Subsequent levels begin in this hip-flexed position.	

Figure 1: Sahrmann Core stability test [19]

The subjects performed exercises without changing the pressure in the cuff more or less than 10 mmHg. Scores were recorded as the highest level was achieved with no pressure change of more or less than 10 mmHg. If subject is unable to maintain pressure in specific level, one level earlier is considered to record the score. If abdominal drawing in maneuver performed correctly, there will be no change in the pressure or slight reduction of pressure. Average of three readings were taken as the final score for the test.

STATISTICAL ANALYSIS

Statistical Analysis was performed using Winpepi Version 11.65 (Abramson 2011), Primer software (Primer-e, Auckland, New Zealand) and Microsoft Excel 2010(Microsoft, Redmond, USA). Descriptive statistics was used to find the mean, median and standard deviation for the outcome variables. Baseline characteristics between the groups were compared by appropriate tests to identify similarity between the groups. Normality Test (Shapiro Wilk) was applied to see the normality of the data. If p value was greater than 0.05 then the normal distribution of the data was considered. If p value was less than 0.05 then data was not considered normally distributed. As the data was not normally distributed, parametric tests such as, paired t test and unpaired t test were not applied. Non parametric test, Mann Whitney U test was applied for the data which was not normally distributed.

RESULT

The study consisted of two groups A and B with 25 subjects each. Demographically the age of subjects in group A was 22.16 ± 1.99 years and Group B was 22.88±1.98 years.

1) **Dynamic Balance measurement by Star Excursion test**

The mean value of dynamic balance of group A (study group) was 93.3 ± 4.26. The mean of dynamic balance group B (control group) is 103.7± 19.9. The Z sub t value is 3. 921.The above table showed that the mean value of group B is higher than the mean value of group and also the value p is <0.0001, hence the mean values of both groups are statistically significant. It indicates that dynamic balance is affected more in high heel users that is group A than flat footwear users group B (Table 1).

Group	N	Mean ± SD	Median	Z sub t value	P value	Shapiro Wilk W*
A	25	93.3± 4.26	94.38	3.921	0.001	0.001
B	25	103.7± 19.9	97.77			0.000

Table 2:Scores of Dynamic Balance of study and control group

2) **Lumbar Lordosis measurement:** The mean lordosis angle of group A was 56.23 ± 6.01. and for group B was 26.93 ± 5.52. The Z sub t value is 6.054. The results of group A were statistically higher than that of group B (p is <0.0001). This indicates that lumbar lordosis angle increased more in high heel users than flat footwear users. (Table 2).

Table 3: Scores of Lumbar Lordotic angle of study and control groups

Group	N	Mean ± SD	Median	Z sub t values	P value	Shapiro Wilk W*
A	25	56.23 ± 6.01	56.12	6.054	0.001	0.165
B	25	26.93 ± 5.52	25.08			0.006

3) **Core Strength measurement:** The mean score of core strength of group A was 1.96 ± 0.93 as compared to that of group B which was 3.32 ± 0.69. The Z sub t value is 4.380. The difference was statistically significant with p value <0.0001. This indicated that core muscle strength was also affected more in high heel users than flat footwear users. (Table 3)

Group	N	Mean ± SD	Median	Z sub t	P value	Shapiro Wilk W*
A	25	1.96 ± 0.93	2	4.38	0.001	0.001
B	25	3.32 ± 0.69	3			0.000

Table 4: Scores of Core strength levels of study and control groups

Thus, our results indicated there was statistically significant difference in all three parameters that is, Dynamic balance, core muscle strength and lumbar lordosis between the two groups.

DISCUSSION

The present study was carried out to see the effect of heel height on balance, lumbar lordosis and core strength between high heel users and flat footwear users. Dynamic balance was assessed by Star Excursion Balance test, Lumbar lordotic angle was measured by flexi ruler method and core muscle strength was assessed by Sahrmann Core stability test. The results of present study show that dynamic balance, lumbar lordosis and core strength is affected more in high heel users than flat footwear users.

In our study, there was a reduction in the mean scores of Dynamic balance in the study group as there was a highly statistical difference (p< 0.0001). The reduction of balance was more in females who wear high heeled shoes on daily basis than females who wear flat footwear on daily basis. The mean reduction in balance score was more in study group as compared to control group, both statistically and clinically.

Balance which is affected has been the result of impaired neuromuscular control because of high heeled shoes. Due to shortening of gastrocnemius and soleus muscles, the length – tension relationship changes, which reduces muscle contraction. As a result,

ability to generate necessary force to control Center of Mass gets reduced, which places greater demands on plantarflexor muscles.[13]
Zhang et al found that prolonged wearing of high heels cause ankle to go into plantarflexion. It also reduces Base of support (BOS) which puts greater demands on lower limb muscles of stance extremity which is typically observed in performing SEBT. This in turn reduces excursion distance. Central Nervous System maintain dynamic balance by combining visual, vestibular and somatosensory systems. Affection of any of these can significantly impairs body's dynamic balance.[1]
Increase in heel height shifts the force and peak pressure from the rear foot and mid foot regions to the forefoot (including toes) region, and the COP location moved forward and to the medial side of the foot. Due to increase in heel height woman stand or walk with an increase in upward displacement of COM resulting in an unstable posture. This unstable posture can increase the risk of falling, which further restricts the movements signified by a decrease in speed of movement, worsened directional control and reduced excursions.[20]
The present study had significant reduction in the mean values of lumbar lordotic angle ($p < 0.001$) in study group compared to control group. This indicates that there was significant reduction in the lumbar lordotic angle in high heel users than flat footwear users.
Anterior shifting of COG affected postural alignment and balance. To maintain this balance, maximum compensatory changes occurred at lumbar spine leading to hyperlordosis. Pelvic position was considered as an essential factor to determine the posture of the lumbar spine. It was observed that anteversion of the pelvis was associated with lumbar hyperlordosis in both the groups.
De Oliveira Pezzan et al in their study analysed the influences of wearing wedge high-heeled shoes on lumbar lordosis and pelvic inclination angles among adolescents aged between 13 and 20 years who were users and nonusers of high heeled shoes and correlated these angles with ages and the time of high-heel use. He found that lumbar lordosis was significantly increased in both the groups. The fact behind this could be user group had already chronically adapted to the type of footwear and its influence over time lead lumbar spine to undergo into hyperlordosis.[21]
Core strength assessment showed, there was significant reduction in mean values ($p < 0.0001$) of core strength in group A that is, study group compared to control group. This indicates that core strength was significantly reduced in high heel users than flat footwear users both statistically and clinically. Abdominal weakness produces exaggerated lumbar lordosis resulting in low back. This is based on anatomic position of female pelvis and function of the abdominal muscles. Postural changes cause excessive anterior tilt and cause low back pain. Wearing of high heels leads to increase in anterior pelvic tilt and cause low back pain. This further causes weakness of abdominal and core muscles.[19,22]
Wilson et al concluded that, regular use of high heeled shoes put greater demands on lower limb muscles, which in turn causes less activation of core muscles and leads to core muscle weakness and performance.[23]
Thus, it was observed that use of high heeled shoes on daily basis affects body's dynamic balance, increases lumbar lordosis and affects core muscle strength.

CONCLUSION

High heeled shoes are commonly used by young females on a daily basis as a requirement of their profession or as a symbol of fashion. High heels may have deleterious effects on the body. Our study concludes that using high heeled footwear leads to increased discomfort in muscles of the lower limbs like the calf muscles which in turn causes balance impairments while walking. There is significant effect of heel height on dynamic balance, lumbar lordosis and core muscle strength in women who regularly wear high heeled footwear which can be correlated to increased episodes of lower lumbar pain, imbalanced gait and postural problems.

We suggest limited use of high heeled footwear with adequate downtime to help improve body dynamics while walking. It is advisable to use heel height upto 2 inches for a limited time so as to avoid risk of falls and musculoskeletal injuries.

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Zhang B, Li S, Zhang Y. Evaluation of Dynamic Posture Control when Wearing High-Heeled Shoes Using Star Excursion Balance Test. Physical Activity and Health. 2017;1(1):1-7.
2. Ko D, Lee H. The Changes of COP and Foot Pressure after One Hour's Walking Wearing High-heeled and Flat Shoes. Journal of Physical Therapy Science. 2013;25(10):1309-1312.
3. Russell BS. The effect of high-heeled shoes on lumbar lordosis: a narrative review and discussion of the disconnect between Internet content and peer-reviewed literature. Journal of chiropractic medicine. 2010 Dec 1;9(4):166-73.
4. Dai M, Li X, Zhou X et al: High-heeled-related alterations in the static sagittal profile of the spino-pelvic structure in young women. European Spine Journal. 2015 Jun; 24:1274-81. 2015, 24:1274-81. 10.1007/s00586-015-3857-6
5. Taga G. A model of the neuro-musculo-skeletal system for human locomotion. Biological cybernetics. 1995 Jul 1;73(2):97-111.
6. Youdas JW, Garrett TR, Egan KS et al. Lumbar lordosis and pelvic inclination in adults with chronic low back pain. Physical therapy. 2000 Mar 1;80(3):261-75.
7. Baaklini E, Angst M, Schellenberg F et al.High-heeled walking decreases lumbar lordosis. Gait & posture. 2017 Jun 1; 55:12-4.
8. Csapo R, Maganaris CN, Seynnes OR et al. On muscle, tendon and high heels. Journal of Experimental Biology. 2010 Aug 1;213(15):2582-8.
9. Lee CM, Jeong EH, Freivalds A. Biomechanical effects of wearing high-heeled shoes. International journal of industrial ergonomics. 2001 Dec 1;28(6):321-6.
10. Afzal F, Manzoor S.Prolong Wearing of High Heeled Shoes Can Cause Low Back Pain. J Nov Physiother 2017:356.
11. Sparrey C, Bailey J, Safaee M, et al. Etiology of lumbar lordosis and its pathophysiology: a review of the evolution of lumbar lordosis, and the mechanics and biology of lumbar degeneration. Neurosurgical Focus. 2014;36(5): E1.
12. Lin RM, Jou IM, Yu CY. Lumbar lordosis: normal adults. Journal of the Formosan Medical Association= Taiwan yi zhi. 1992 Mar;91(3):329-33.
13. Weon J, Cha H. The influence of high heeled shoes on balance ability and walking in healthy women. Journal of Physical Therapy Science. 2018;30(7):910-912.
14. Ko J, Wikstrom E, Li Y, Weber M, Brown C. Performance Differences Between the Modified Star Excursion Balance Test and the Y Balance Test in Individuals with Chronic Ankle Instability. Journal of Sport Rehabilitation. 2019;1-20.
15. Cleveland MA. The effect of core strength on long distance running performance. Western Washington University March 2011
16. Elnaggar IM, Nordin M, Sheikhzadeh A et al. Effects of spinal flexion and extension exercises on low-back pain and spinal mobility in chronic mechanical low-back pain patients. Spine (Phila PA 1976) 1991;16(8):967-72.
17. Malarvizhi D, Varma S, Vpr S. Measurement Of Anterior Pelvic Tilt In Low Back Pain-An Observational Study. Asian Journal of Pharmaceutical and Clinical Research. 2017;10(4):115
18. Levine D, Walker J, Tillman L. The effect of abdominal muscle strengthening on pelvic tilt and lumbar lordosis. Physiotherapy Theory and Practice. 1997;13(3):217-226.
19. Faries M, Greenwood M. Core Training: Stabilizing the Confusion. Strength and Conditioning Journal. 2007;29(2):10.
20. Hapsari V, Xiong S. Effects of high heeled shoes wearing experience and heel height on

human standing balance and functional mobility. Ergonomics. 2015;59(2):249-264.
21. De Oliveira Pezzan P, João S, Ribeiro A et al. Postural Assessment of LumbarLordosis and Pelvic Alignment Angles in Adolescent Users and Nonusers of HighHeeled Shoes. Journal of Manipulative and Physiological Therapeutics. 2011;34(9):614-621.
22. Sharrock C, Cropper J, Mostad J, et al. A pilot study of core stability and athletic performance: is there a relationship? International journal of sports physical therapy. 2011 Jun;6(2):63
23. Willson JD, Dougherty CP, Ireland ML,et al. Core stability and its relationship to lower extremity function and injury. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2005 Sep 1;13(5):316-25.

How to cite this article: Gayatri Joshi, Himanshu Pathak, Vijaya Bagade, Shweta Naidu. The effect of heel height on balance, lumbar lordosis and core muscle strength among young healthy Indian females. *Int J Health Sci Res.* 2024; 14(1):135-142. DOI: *10.52403/ijhsr.20240117*

******