NARRATIVE REVIEW

Biomechanical effects of high heeled shoes on neck pain among females: A narrative review

Tahir Mahmood[1], Rubab Naqvi[2], Iqra Waseem[3], Abdul Salam[4]

Abstract

Neck pain is the fourth leading cause of disability, and is the most common musculoskeletal disorder. High-heel shoes, one of the significant identities of females, cause pain in the neck as well as in feet and ankle regions. The current narrative review was planned to explore evidence to highlight the biomechanical factors of high-heel shoes as the source of neck pain, which mostly remains undiagnosed. PubMed and Google Scholar search engines were explored for full text of research articles published in English language from 2016 to 2021. Of the 82 studies initially found, 22(27%) were shortlisted for full-text assessment, and, of them, 6 (27.27%) were selected for detailed analysis. Despite other contributing factors, kinematics and kinetics should be considered primarily during neck pain management. Based on best available evidence, high heels increase the individual's height, but result in significant decrease in trunk flexion. Evidence also suggests that the type and width of heels do not affect as much as the height of the heels in the context of pain and functional issues in the cervical region.

Keywords: Biomechanics, Females, High heels, Neck pain, Musculoskeletal disorders, Shoes.

DOI: https://doi.org/10.47391/JPMA.6572
Submission completion date: 02-04-2022
Acceptance date: 24-08-2022

Introduction

The neck consists of seven vertebrae that connect the head with the torso, providing mobility and three-dimensional (3D) movement of the head. The anatomy of the human neck is a group of four compartments; vertebral, visceral and two vascular compartments.[1] Any abnormality, inflammation, or harm to the supporting structures, like ligaments, and muscles, can cause neck pain.[2] Neck pain is the fourth most leading cause of disability and musculoskeletal disorder after disability-adjusted life years (DALYs) globally after heart disease, lower respiratory tract infection and cardiovascular diseases.[3] Kinematically, the human neck is mostly affected by poor posture, which may lead to muscular imbalance. In terms of kinetics, people mostly experience neck pain because of terrible posture, overuse, or due to pulled muscles. On the other hand, different diseases, such as rheumatoid arthritis (RA), meningitis, and cancer, are also the source of neck pain.[4] There is a strong relationship among sitting position, neck posture and neck pain.[5] Regarding risks factors, age, gender and genetics are non-modifiable factors, while smoking, tobacco exposure and mental health, are modifiable risk factors.[6] Neck pain is more prevalent in widowed/separated women having low educational and socioeconomic status and also in working women who have to work in sitting and leaning positions for longer duration of time.[7] There are eight themes that describe different ways people think about the causes of their symptoms related to neck pain. These themes are: Posture and Movement; Mechanism, Structures and Tissues; Predisposition or Lifestyle factors; Emotional triggers; Fatigue or Insomnia; Symptom factor, Intervention-related factors; and Environmental triggers.[8]

High-heeled shoes and neck pain

Females use numerous behavioural strategies in order to seek attention, and wearing high-heeled shoes boosts female physical attraction.[9] Compared to flat sole, high-heeled shoes cause an increase in vertical and anterior-posterior (AP) ground reaction force (GRF). High-heeled shoes potentially change centre of mass, and, hence, increase the risk of instability.[10] High-heeled shoes do not only have detrimental effects on feet and ankle, but also affect knees, hips and spine. During walking with high-heels, there is increased knee joint extension mechanism due to bone-on-bone forces.[11] High-heels lift during walking and disrupt the lower limb biomechanical pattern with undue stress on the involved limb musculature.[12] During walking, high-heels cause an increase in plantar flexion at the ankle, with flexion at the knee joint, lumbar lordosis, and disturbance in step length.[13]

Researchers have identified the role of stiletto heels (10cm) for the increase in muscular activity of cervical paraspinal muscles. Furthermore, it was observed that young adults, especially those aged 22-25 years, face significantly

[1,4]Imran Idrees Institute of Rehabilitation Sciences, Sialkot Medical College, Sialkot, Pakistan; [2]Department of Physiotherapy, Azra Naheed Medical College, The Superior University, Lahore, Pakistan; [3]University Institute of Physical Therapy, The University of Lahore, Lahore, Pakistan.
Correspondence: Tahir Mahmood. e-mail: tahirmahmoodphysio@gmail.com
ORCID ID. 0000-0003-0175-5248

increased activity of cervical muscle while striking heel and toe-off compared to middle-aged individuals of 40-45 years, that can be due to age-related active work involvement. It is suggested that prolonged wearing of this type of footwear even by individuals without neck pain is not safe and may lead to chronic paraspinal muscle fatigue, resulting in the neck repetitive strain injury.[14] There is positive relationship between heels' height and head protrusion angle that means each centimetre increase in heel's height affect the neck angle.[15] Four-inch heel leads to forward head posture, and forward/lifted chest is a compensatory movement to keep balance which makes the muscles tight, and lead to neck pain.[9] High heels cause increased spinal curvatures, hyperextension at knees, a non-neutral position of the ankle and increased pressure on the balls of the feet. Besides, 1 inch of heels makes <22% while 2-3 inches give <57-76% pressure over the forefoot.[16] High heels increase the overall height, which results in reduced trunk flexion angle significantly.[17] Young adults who wear high heel (>5cm) for more than 8 hours/day usually suffer from mild to moderate neck disability.[18] Women who wear high heel up to 4cm experience poor dynamics, mobility and postural control. Experienced wearers exhibit control ankle strategy and centre of gravity directional control that prevents them from falling.[19]

The current narrative review was planned to find out the involvement of high-heeled shoes for causing neck pain due to the poor biomechanical involvement of spine and muscular imbalance caused by them, especially among females.

Methods and Results

The narrative review entailed exploring PubMed and Google Scholar search engine databases for full-text research articles published in the English language from 2016 to 2021. The search was conducted through appropriate key words (Table 1).

The risk of bias was assessed using Pedro Score.[20]

Further methodological quality assessment was performed by using the Critical Appraisal Skills Programme (CASP).[21]

Studies addressing other factors of high heels, including low back pain, lumbar lordosis and hip pain, were excluded and so were case studies, short reports, experimental studies, those published in a language other than English, and studies having <7 points on CASP.

Of the 82 studies initially found, 22(27%) were shortlisted for full-text assessment. After CASP assessment, 6(27%) studies were shortlisted[22-27] (Table 2). For detailed analysis, 6(27.27%) studies were selected; 3(50%) with CASP score 7, and 3(50%) with CASP score 8.

Table-1: Data search and key words

No. of Hits on Data Search			
Custom range	**Key word**	**PubMed**	**Google scholar**
2016-2021	Neck Pain in females	6622	28400
	High heeled Shoes	73	11400
	High heeled Shoes biomechanics	40	4160
	Neck pain and high heeled shoes	01	16600
	Neck Pain in females and High heeled shoes and biomechanics and Neck pain	-	2370
	Neck Pain in females or High heeled and High heeled biomechanics or Neck pain and high heeled shoes	-	2370

Table-2: High-heeled shoes and neck pain studies.

Autho rs	Type of study	Statement	Result	CASP rating	Level of Evidence
Weitkunat T, et al[22], 2016	Cross -sectional	Influence of high-heeled shoes on the sagittal balance of the spine and the whole body	High heels increase the knee flexion and ankle flexion resulting increased cervical lordosis in order to adapt to the shift of body COG	8	5
Kisu Park K, et al[23], 2016	Analytical	Effects of the height of shoe heels on muscle activation of cervical and lumbar spine	During heel strike and toe off, there is significant increase in activation of paraspinalis cervicis and erector spinae in the subjects wearing under 10 cm high heel.* Statistical significance was $p<0.05$.	7	5
Baaklini E et al[24], 2017	Analytical	High-heeled walking decreases lumbar lordosis	During walking, heel's height influence the motion of pelvis and spine. The low-heeled shoes affect the subjects' trunk kinematics less than high-heeled shoes compared to barefooted walking during gait.	7	5
Genebra CVDS et al[25], 2017	Cross sectional	Prevalence and factors associated with neck pain: a population-based study	High prevalence of neck pain was recorded with sitting and leaning position i.e. Prevalence ratio = 1.55	7	6
Rollings AA[26], 2018	Cross sectional	revalence and factors associated with neck pain: a population-based study	High prevalence of neck pain was recorded with sitting and leaning position i.e. Prevalence ratio = 1.55	7	6
Özdinç S et al [27], 2019	Cross sectional	revalence and factors associated with neck pain: a population-based study	High prevalence of neck pain was recorded with sitting and leaning position i.e. Prevalence ratio = 1.55	7	6

Discussion

Neck pain, the foremost common musculoskeletal problem, ultimately results in substantial disability, and is the fourth leading cause of musculoskeletal pain after low back pain.[3] In general population, overall prevalence ranges between 0.4% and 86.8% (mean: 23.1%); point prevalence ranges from 0.4% to 41.5% (mean: 14.4%); and 1-year prevalence ranges from 4.8% to 79.5% (mean: 25.8%). Prevalence is mostly higher in women and in high-income countries compared to low- and middle-income countries (LMICs), and it is also different in urban and rural areas.[29] On the other hand, the international or global point prevalence of neck pain is 4.9% (95% confidence interval [CI': 4.6 to 5.3). Disability-adjusted life years (DALYs) increased from 23.9 million in 1990 to 33.6 million in 2010. Out of all 291 conditions studied in the Global Burden of Disease 2010 Study, neck pain was the 4th highest with regard to disability as measured by years lived with disability (YLDs), and 21st with regard to the overall disease burden.[29]

Increased postural sway when standing with eyes open and increased cervical range of motion (ROM) in flexion/extension will result in the ultimate reduction of neck pain. In short, the most important factor associated with changes in both neck pain and neck disability is cervical ROM in flexion/extension.[30] The wearing of high-heeled shoes is increasing day by day in this era of fashion.[31] They are preferred for attractiveness, but studies show that they are detrimental to health. According to a recent study, high heel changes the joint mechanics during walking which may result in abnormalities of foot.[32] Another recent study compared the biomechanical effects of high heel and low heel on jogging and running, and showed there was decreased ROM during stance phase with high-heel shoes and also increased weight-bearing on the ankle, knee and hip joints.[33] Long-term wearing of high heels also affects the arches of the foot that effectively transfer the body weight to the ground.[34] High heels also disturb body balance and functional activity.[35] High heels (<3.9cm) activate cervical and lumbar muscles, and also affect postural control.[36,37] Wearing high-heeled shoes not only disturbs the body balance, but also affects the trunk muscles. Because of high-heeled shoes, trunk muscle has to work more in order to maintain the balance of body mass and centre of gravity (COG). As heels' height increases, this proportionally disturbs the body balance, trunk stability, muscle activation of ankle and knee, muscle activation of the cervical and lumbar spine, bodyweight distribution, and walking speed.[39] This statement is proven by the fact that experienced high-heel wearers have considerably smaller centre of pressure (COP) variances (AP) for 8-10cm heels, have smaller COP velocities (AP) for all heels, and smaller COP variances and COP velocities (Medial Lateral) for 10cm heels. Even though women wearing high heels are considered prettier, younger, sexier and more elegant,[39] studies showed that due to wearing high heels (7-10cm), the standing balance and functional mobility become worse because heel elevation induces lower limb muscle effort, particularly calf muscles.[35] Recent studies showed that in the course of manufacturing, besides the design, material and shape of the shoes, more importance should be given to the proper height of the heels.[40] In terms of biomechanics, high-heel shoes cause great toe valgus, musculoskeletal pain, and first-party injury, while there is no conclusive proof for osteoarthritis and second-party injury.[41] A recent study reported a positive association between shoulder discomfort and high-heel shoes among women (p=0.03). But there is no specific study indicating the specific size of heels to prevent discomfort. It has been recommended, however, that women should not wear high heels >3 hours per day to prevent discomforts.[42] It is unavoidable to wear heels with a narrow base, but a wide high heel of 3cm is better to avoid the risk of slipping.[43] Furthermore, better pelvic floor muscle works well with heals of 3cm or more thickness and height of 3-5cm, which will minimise the biomechanical risk of COG shift and stress on the spine.[44]

In the light of all the studies discussed above, muscle activation in the paraspinal cervicis and erector spine at heel strike and toe-off (except that of paraspinalis cervicis at toe-off event) differed significantly with 10cm heels compared to the barefoot condition. At heel strike, this muscle activation was significantly greater with the 10cm heels compared to that with 4cm heels. The human body responds to high heels by flexing or forward bending at the hips and spine in order to compensate for the imbalance. In addition to lumbar spine flattening, posterior displacement of the head and thoracic spine also occurs because of high heels. In addition to low back and shoulder pain, high heels are also a potential source of neck pain as they disrupt the natural form of the body.

It is the need of the hour to pay attention to this cause of neck pain also. Many other factors, including body mass index (BMI), secondary disease, job nature and working hours have not been focussed upon, but can also be a secondary source of neck pain with poor mechanics. It is not clear exactly which type and height of the heel is the initial point of causing harmful effects on the neck. Further research is needed in this regard.

Conclusion

The height of heel is directly proportional to the impact of the detrimental force all over the body. It changes the

biomechanical pattern of the body, starting from the lower limb and ultimately affecting the neck. Despite other contributing factors, kinematics and kinetics should be considered first during its management. The role of patient education can play a key role as a prevention strategy.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

References

1. Frost BA, Camarero-Espinosa S, Foster EJ. Materials for the Spine: Anatomy, Problems, and Solutions. Materials 2019;12:253. doi: 10.3390/ma12020253.
2. Kashif M, Tahir S, Ashfaq F, Farooq S, Saeed W. Association of myofascial trigger points in neck and shoulder region with depression, anxiety and stress among university students. J Pak Med Assoc 2021;71:2139-42. doi: 10.47391/JPMA.375.
3. Hurwitz EL, Randhawa K, Yu H, Côté P, Haldeman S. The Global Spine Care Initiative: a summary of the global burden of low back and neck pain studies. Eur Spine J 2018;27(Suppl 6):796-801. doi: 10.1007/s00586-017-5432-9.
4. Devlin VJ . Cervical Spinal Disorders: Nonsurgical Management Strategies. In: Devlin VJ, eds. Spine Secrets, 3rd ed. Philadelphia, USA: Elsevier Inc, 2020; pp 128.
5. Ariëns GA, Bongers PM, Douwes M, Miedema MC, Hoogendoorn WE, van der Wal G, et al. Are neck flexion, neck rotation, and sitting at work risk factors for neck pain? Results of a prospective cohort study. Occup Environ Med 2001;58:200-7. doi: 10.1136/oem.58.3.200.
6. Hogg-Johnson S, Van Der Velde G, Carroll LJ, Holm LW, Cassidy JD, Guzman J, et al. The burden and determinants of neck pain in the general population: results of the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders. Spine (Phila Pa 1976) 2008;33(Suppl 4):s39-51. doi: 10.1097/BRS. 0b013 e31816454c 8.
7. Genebra CV, Maciel NM, Bento TP, Simeão SF, De Vitta A. Prevalence and factors associated with neck pain: a population-based study. Braz J Phys Ther 2017;21:274-80. doi: 10.1016/j.bjpt.2017.05.005
8. Walton DM, Balsor B, Etruw E. Exploring the causes of neck pain and disability as perceived by those who experience the condition: a mixed-methods study. Int Sch Res Notices 2012;2012. doi: 10.5402/2012/971328
9. Prokop P, Švancárová J. Wearing high heels as female mating strategy. Pers Individ Dif 2020;152:109558. doi: 10.1016/j.paid.2019.109558
10. Mika A, Oleksy Ł, Mikołajczyk E, Marchewka A, Mika P. Changes of bioelectrical activity in cervical paraspinal muscle during gait in low and high heel shoes. Acta Bioeng Biomech 2011;13:27-33.
11. Simonsen EB, Svendsen MB, Nørreslet A, Baldvinsson HK, Heilskov-Hansen T, Larsen PK et al. Walking on high heels changes muscle activity and the dynamics of human walking significantly. J Appl Biomech 2012;28:20-8. doi: 10.1123/jab.28.1.20
12. Rabusin CL, Menz HB, McClelland JA, Tan JM, Whittaker GA, Evans AM, et al. Effects of heel lifts on lower limb biomechanics and muscle function: a systematic review. Gait Posture 2019;69:224-34. doi: 10.1016/j.gaitpost.2019.01.023.
13. Wiedemeijer MM, Otten E. Effects of high heeled shoes on gait. A review. Gait Posture 2018;61:423-30. doi: 10.1016/j.gaitpost.2018.01.036
14. Mika A, Oleksy Ł, Mikolajczyk E, Marchewka A. Evaluation of the influence of low and high heel shoes on erector spine muscle bioelectrical activity assessed at baseline and during movement. Med Rehabil 2009;13:9-18.
15. Karimi N, Moedi SE, Rahnama L, Arsalan SA, Abbas Nia S. Assessment of the High-heel Shoes Effect on Head Protrusion Angle. Physical Treatments. 2016; 6: 109-14. doi: 10.18869/nrip.ptj.6.2.109
16. Wan KWF. Three-dimensional insole design for relieving plantar pressures in high-heeled shoes. In: Yu WW, Yick K. [Online] 2018 [Cited 2022 March 11]. Avaliable from URL: https:// theses. lib. polyu. edu. hk / handle /200/9785
17. Lee CM, Jeong EH, Freivalds A. Biomechanical effects of wearing high-heeled shoes. Int J Ind Ergon 2001;28:321-6. doi: 10.1016/S0169-8141(01)00038-5
18. Ghadage PP, Sagar JH. Prevalence of Neck Dysfunction in Women Using High Heeled Footwear Working in IT Profession. Indian J Public Health Res Dev. 2020;11(5).
19. Yu DF, Yu YG, Gao L, Shan GB, Wang L. The influence of different-height heel shoes on motor function of lower limb joints in the young female performers. J Mech Med Biol 2021;21:2050010.
20. de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. Aust J Physiother 2009;55:129-33. doi: 10.1016/s0004-9514(09)70043-1
21. Critical Appraisal Skills Programme. CASP Qualitative Studies Checklist [Online] 2018 [Cited 2022 September 7]. Available from URL: https://casp-uk.net/casp-tools-checklists/
22. Weitkunat T, Buck FM, Jentzsch T, Simmen H-P, Werner CM, Osterhoff G. Influence of high-heeled shoes on the sagittal balance of the spine and the whole body. Eur Spine J 2016;25:3658-65. doi: 10.1007/s00586-016-4621-2.
23. Park K, Kim Y, Chung Y, Hwang S. Effects of the height of shoe heels on muscle activation of cervical and lumbar spine in healthy women. J Phys Ther Sci 2016;28:956-9. doi: 10.1589/jpts.28.956.
24. Baaklini E, Angst M, Schellenberg F, Hitz M, Schmid S, Tal A, et al. High-heeled walking decreases lumbar lordosis. Gait Posture 2017;55:12-4. doi: 10.1016/j.gaitpost.2017.03.035.
25. Genebra CVDS, Maciel NM, Bento TPF, Simeão SFAP, De Vitta A. Prevalence and factors associated with neck pain: a population-based study. Braz J Phys Ther 2017;21:274-80. doi: 10.1016/j.bjpt.2017.05.005.
26. Rollings AA. The effects of heel height on head position, long-term average spectra, and perceptions of female singers. J Voice 2018;32:127.e15-127.e23. doi: 10.1016/j.jvoice.2017.03.005.
27. Özdinç S, Kayabınar E, Özen T, Turan FN, Yılmaz S. Musculoskeletal problems in academicians and related factors in Turkey. J Back Musculoskelet Rehabil 2019;32:833-9. doi: 10.3233/BMR-181171.
28. Hoy D, Protani M, De R, Buchbinder R. The epidemiology of neck pain. Best Pract Res Clin Rheumatol 2010;24:783-92. doi: 10.1016/j.berh.2011.01.019.
29. Hoy D, March L, Woolf A, Blyth F, Brooks P, Smith E, et al. The global burden of neck pain: estimates from the global burden of disease 2010 study Ann Rheum Dis 2014;73:1309-15. doi: 10.1136/annrheumdis-2013-204431.
30. Meisingset I, Stensdotter A-K, Woodhouse A, Vasseljen O. Neck motion, motor control, pain and disability: A longitudinal study of associations in neck pain patients in physiotherapy treatment. Man Ther 2016;22:94-100. doi: 10.1016/j.math.2015.10.013.
31. Linder M, Saltzman CL. A history of medical scientists on high heels. Int J Health Serv 1998;28:201-25.
32. Afzal F, Manzoor S. Prolong wearing of high heeled shoes can cause low back pain. J Nov Physiother 2017;7:2. doi: 10.4172/2165-7025.1000356
33. Fu F, Zhang Y, Shu Y, Ruan G, Sun J, Baker JS, et al. Lower limb mechanics during moderate high-heel jogging and running in different experienced wearers. Hum Mov Sci 2016;48:15-27. doi: 10.1016/j.humov.2016.04.002

34. Yin CM, Pan XH, Sun YX, Chen ZB. Effects of duration of wearing high-heeled shoes on plantar pressure. Hum Mov Sci 2016;49:196-205. doi: 10.1016/j.humov.2016.06.005.
35. Hapsari VD, Xiong S. Effects of high heeled shoes wearing experience and heel height on human standing balance and functional mobility. Ergonomics 2016;59:249-64. doi: 10.1080/00140139.2015.1068956.
36. Park K, Kim Y, Chung Y, Hwang S. Effects of the height of shoe heels on muscle activation of cervical and lumbar spine in healthy women. J Phys Ther Sci 2016;28:956-9. doi: 10.1589/jpts.28.956.
37. Sun D, Gu Y, Mei Q, Shao Y, Sun J, Fernandez J. Effect of heel heights on female postural control during standing on a dynamic support surface with sinusoidal oscillations. J Mot Behav 2017;49:281-7. doi: 10.1080/00222895.2016.1191423.
38. Wan FK, Yick K-L, Winnie W. Effects of heel height and high-heel experience on foot stability during quiet standing. Gait & posture 2019;68:252-7. doi: 10.1016/j.gaitpost.2018.12.004
39. Guéguen N, Stefan J, Renault Q. Judgments toward women wearing high heels: a forced-choice evaluation. Fash Text 2016;3:1-7. doi: 10.1186/s40691-016-0058-9
40. Hyun S-H, Kim Y-P, Ryew C-C. Effect on the parameters of the high-heel shoe and transfer time of ground reaction force during level walking. J Exerc Rehabil 2016;12:451. doi: 10.12965/jer.1632592.296.
41. Barnish MS, Barnish J. High-heeled shoes and musculoskeletal injuries: a narrative systematic review. BMJ open 2016;6:e010053. doi: 10.1136/bmjopen-2015-010053.
42. Malick WH, Khalid H, Mehmood Z, Hussain H. Association of musculoskeletal discomfort with the use of high heeled shoes in females.J Pak Med Assoc. 2020;70:2199-204. doi: 10.47391/JPMA.536.
43. Park S, Park H, Park J. Effect of heel base area and walking speed on the utilized coefficient of friction during high-heeled walking. Work 2019;64:397-405. doi: 10.3233/WOR-192983.
44. Wang Y, Shi C, Jiao W, Yu W, Shi G, Zheng J. Wearing high heels with an appropriate height is protective for pelvic floor function. Transl Androl Urol 2021;10:2493. doi: 10.21037/tau-21-486.