ORIGINAL ARTICLE

The Impact of Load Carriage and High-heeled Shoes on Gait During Incline Walking

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ABSTRACT

Introduction: High-heeled footwear lacks sufficient cushioning at the heel, leading to direct transmission of impact forces to the body, which may contribute to musculoskeletal strain. While previous studies have examined the effects of high heels on gait and posture, limited research has investigated the combined impact of high-heeled walking, load carriage, and surface incline on lower limb biomechanics. This study seeks to address this gap by analyzing the forces exerted on the ankle joint and Achilles tendon under these conditions. **Materials and Methods:** Fifteen young healthy local university female undergraduates were assessed in biomechanics lab for the kinetic impact of walking under various conditions, comparing barefoot and high-heeled shoe conditions with and without load carriage. The analysis encompassed walking on both level and inclined surfaces at participants' preferred walking speeds. Utilizing the inverse dynamic method, the forces exerted on the ankle joint and Achilles tendon were calculated. **Results:** Variations in VGRF can indicate potential stress on joints and tissues; however, the results showed no statistically significant differences in maximum VGRF between conditions. Nevertheless, the study observed a consistent increase in both ankle joint and tendon forces with the steepening of slope across all heel height and load carriage conditions. **Conclusion:** The results of this research enhance our understanding of the interactions between humans and high-heels, providing insights to enhance the performance of the musculoskeletal system. This knowledge is valuable for prioritizing women's safety and health in terms of gait and posture while wearing high-heeled footwear.
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INTRODUCTION

High-heels feature a raised heel that lifts the wearer higher off the ground than the toe, elevating the heel above the fore-part of the footwear. Despite concerns regarding comfort and support, high-heeled shoes continue to be widely embraced, with a significant number of women integrating them into their daily attire (1). Studies suggest that frequent wearing high-heeled shoes can lead to an uneven distribution of pressure beneath the foot, resulting in adverse effects on foot structure (2). Indeed, compared to going barefoot, the design of high heels presents challenges in maintaining balance and increases the risk of falls due to movement of the body center of gravity (COG) and a reduction in the base of support (BOS) (3). While the human body can adapt to these stability challenges to some extent, these adjustments can have significant impacts on the musculoskeletal system (4, 5).

The adverse effects experienced by women are not solely attributable to heel height; load carriage also plays a significant role. Over the past few years, women's backpack sales have seen a notable increase of 28%, while sales of women's handbags have gradually declined. In response to significant shifts in physical performance, the interest in understanding the impact of load carriage has led to recommendations suggesting that backpack weight should be restricted to 10% to 15% of body weight (6). Studies suggest that the pivotal mass capable of modifying gait pattern and walking posture, thereby eliciting significant effects on people carrying a load equivalent to 10% of body mass (7, 8).

Research examining the distribution of loads beneath the foot with varying heel heights dated back to the early 1930s. Findings indicate that carrying loads increases joint moments and powers, contributing to imbalanced posture and gait movements in women wearing high-heeled shoes. Moreover, walking while carrying a load significantly impacts spatio-temporal parameters

(6, 9). The critical load for carriage is approximately 10% of body weight. Vertical Ground Reaction Force (VGRF) is a key measurement in gait analysis as it offers valuable insights into the interaction between the body and the ground during walking, serving as a proxy to assess the additional stress imposed by high-heels and its biomechanical impact on gait and posture. Symmetrical load carriage increases VGRF, while uneven loads carriage exceeding 20% of body weight result in considerable increase in low back moment and alterations in trunk and pelvis alignment (10). Increasing walking speed while carrying a heavy backpack could function as a compensatory measure to minimize body instability when walking uphill.

Previous research has predominantly concentrated on investigating the impacts of high-heels (11, 12), various types of load carriage (13), or both (14) on lower extremities. However, studies examining the combined influence of high-heeled shoes and carrying load specifically during incline walking are currently scarce. Incline walking presents a significant challenge in daily activities, involving a biomechanical shift from level to uphill walking that requires increased exertion from leg muscles (15, 16). During uphill walking, ankle extensor muscles play a crucial role in producing positive work to raise the COG (17, 18), potentially increasing the risk of muscle fiber damage (19).

High-heeled shoes can significantly alter biomechanics, often leading to increased stress on the ankle and other lower extremity joints. Research indicates that wearing high heels can increase vertical ground reaction forces (VGRF) by 30-50% compared to flat surfaces, which can lead to greater force transmission to the body, potentially contributing to musculoskeletal discomfort and injury risk (20, 21). In particular, the elevated forces on the ankle joint are associated with an increased likelihood of conditions like Achilles tendinopathy, ankle instability, and even chronic foot discomfort (22). These findings highlight the need for understanding the biomechanical effects of high heels, especially in populations that wear them regularly, such as young women in professional settings. This research can enhance fundamental understanding of human interactions with high-heeled shoes and develop knowledge to optimize human musculoskeletal system performance, whilst preserve women's safety and health in gait and posture.

MATERIALS AND METHODS

High-Heeled Shoes

This study utilized a particular high-heels featuring a heel height of 2.5 inches (6.35 cm) and a diameter of 1 cm at the tip base (see Fig. 1a). A heel height of 2.5 inches is considered a mid-height heel, frequently chosen for professional and social settings, making it a representative example of footwear commonly chosen by many individuals. Similarly, a heel base diameter of 1 cm represents the typical stiletto design, which is associated with stability challenges and increased localized stress on the forefoot and tendons, thereby heightening biomechanical demands on the lower extremities. The high-heels size was standardized to US 7 which is the most common size for women. The control variable for the study was walking barefoot. Prior research has indicated that occasional wear of high-heeled shoes can lead to a reduction in foot pronation during the stance phase of gait (23).

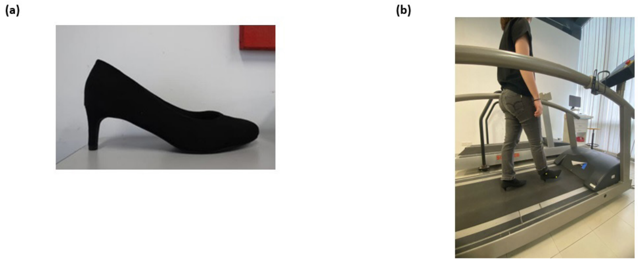

Fig 1 : (a) High-heeled shoes. (b) Experiment setup

Load Carriage and Incline Slope

This study has adopted a load weight equivalent to 10% of the body mass. The control variable for the study is zero load weight to highlight the observed differences. For the safety concern, a 10% incline slope was chosen for this study (24). The slope gradient can be determined:

$$\text{Degree} = \tan^{-1}\left(\frac{\text{Slope Percentage}}{100}\right) \tag{1}$$

Participants

This study enlisted fifteen local female undergraduates who were young (mean age 22.93 ± 0.80 years) with foot sized of US 7, healthy and from the same geographical area. All participants exhibited a normal body mass index (BMI), considering its potential impact on foot force distribution and the provision of varied gait parameters (25). Participants were screened for the absence of postural deformities such as flat feet and high arches, orthopaedic issues, or any lower extremity diseases. The physical anthropometry data of the participants with normal BMI are outlined in Table I. The research was conducted at Universiti Tunku Abdul Rahman, with ethical clearance obtained from the university (U/SERC/175/2022). Informed consent was obtained from all participants before their involvement in the study.

Table I: Characteristics of 15 Female Participants.

Variables	Mean ± Standard Deviation
Age (years)	22.93±0.80
Body Mass (kg)	54.04±7.41
Body Height (m)	1.63±0.03
Length of Leg (m)	0.94±0.02

Experimental Protocol

Prior to commencing testing, anthropometric data concerning the lower extremities, including body height, body mass and leg length were taken and documented. The testing consisted of eight conditions, each repeated twice to obtain an average result, as shown in Table II. In the loaded condition, a load equal to 10% of body mass was applied, whereas no load was applied in the unloaded condition. Markers were placed on the knee joint, ankle joint, heel and toe of the participants' right limb.

Table II: Description of Different Conditions.

No	Condition
1	Level walking with barefoot unloaded
2	Level walking with high-heeled unloaded
3	Level walking with barefoot loaded
4	Level walking with high-heeled loaded
5	10% Incline walking with barefoot unloaded
6	10% Incline walking with high-heeled unloaded
7	10% Incline walking with barefoot loaded
8	10% Incline walking with high-heeled loaded

All participants walked at their preferred speed on an instrumented treadmill equipped with two force plates (HP Cosmos Gaitway) (see Fig. 1b). There were eight conditions to be completed, with each condition repeated three times to obtain an average outcome. Participants walked on the treadmill for 2 minutes per condition. Adequate break time was provided between trials. Kinetic data was collected using the associated software (Gaitway, Traunstein) at a frequency of 100 Hz. Joint angular displacement of the lower extremities was assessed using Kinovea video analysis software (Kinovea.org).

Data Analysis

Fig 2. illustrates the constructed free body diagram for level barefoot walking model. The forces exerted include the VGRF, Achilles tendon (FAT), and ankle joint (ANK) forces which have been analyzed across different conditions. The comparison between barefoot and high-heeled walking was likely included to establish a baseline for understanding how high heels influence biomechanical factors. Barefoot walking represents a natural, unrestricted condition, providing measurable evidence for specific impacts on tendons and joints. Prior to statistical analysis, all data were normalized to mitigate inter-individual differences (26). An independent-means t-test was conducted using the Statistical Package for the Social Sciences (IBM SPSS Statistics, Version 27) to analyze the kinetic data, with the significance level set at .05. The t-value quantifies the size of the difference relative to the variability in the sample data, expressed in units of standard error, providing a standardized measure for comparison (27).

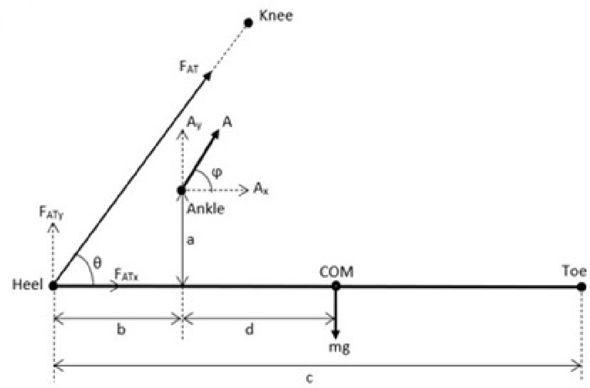

Fig 2 : Free body diagram for level barefoot model. θ is the angle between FAT to right horizontal. a, b, c and d are the heel height, length of FAT to ankle, foot length and length of ankle to COM respectively.

RESULTS

Table III presents the VGRF, FAT, and ANK forces along with their corresponding statistical values for two shoe conditions: (i) barefoot and (ii) high-heeled shoes. These values are categorized across various conditions, including level unloaded, level loaded, inclined unloaded, and inclined loaded. Participants generally exhibited higher VGRF in high-heeled conditions compared to barefoot walking. However, these differences were not statistically significant across any of the tested conditions, suggesting that while high heels may contribute to increased VGRF, the variations may not be robust enough to confirm a systematic effect under these specific conditions. In contrast, the ANK showed a significant increase in inclined conditions when wearing high-heeled shoes ($t(28) = -4.533$, $p < .0001$ for incline unloaded; $t(28) = -4.590$, $p < .0001$ for incline loaded), highlighting a pronounced biomechanical impact due to the combined effects of incline and footwear. However, the lack of significant change in level conditions ($t(28) = -2.264$, $p = .031$; $t(28) = -.701$ $p = .489$) suggests that the influence of high heels on ANK force is more pronounced when the walking surface involves an incline, likely due to the additional mechanical demand placed on the ankle. Similarly, FAT also increased significantly in inclined conditions for both loaded and unloaded groups ($t(28) = 4.229$, $p < .0001$ for inclined unloaded; $t(28) = 4.575$, $p < .0001$ for inclined loaded), indicating a consistent trend of heightened musculoskeletal strain under these scenarios. This finding underscores the compounding effects of incline and high-heeled footwear, particularly in activities that involve sustained or dynamic loading.

Table III: Normalized VGRF, ankle joint force and Achilles tendon force during level and incline walking in barefoot and high-heeled shoes.

Parameters	Variables	Mean ± Standard Deviation		p-value
		Barefoot	High-heeled	
VGRF (N/BW)	Level unloaded	1.04±0.09	1.06±0.11	.557
	Level loaded	1.09±0.11	1.10±0.11	.797
	Inclined unloaded	1.01±0.08	1.05±0.13	.279
	Incline loaded	1.06±0.13	1.09±0.10	.232
Ankle Joint Force (N/BW)	Level unloaded	0.24±0.09	0.30±0.05	.031
	Level loaded	0.32±0.09	0.34±0.07	.489
	Inclined unloaded	0.58±0.25	1.04±0.30	<.0001*
	Incline loaded	0.76±0.30	1.96±0.97	<.0001*
Archilles Tendon Force(N/BW)	Level unloaded	-1.25±0.10	-1.33±0.14	.082
	Level loaded	-1.36±0.14	-1.37±0.17	.763
	Inclined unloaded	-1.53±0.25	-2.02±0.38	<.0001*
	Incline loaded	-1.74±0.33	-2.98±0.99	<.0001*

Table IV summarizes the mean and standard deviation values for VGRF, ANK, and FAT forces under both unloaded and loaded conditions. While variations in VGRF were observed with and without a loaded backpack, the changes were not statistically significant, indicating that load carriage alone had minimal impact on vertical ground reaction forces across the tested scenarios. In contrast, significant increases were noted in ANK and FAT under specific conditions, particularly during level barefoot walking ($t(28) = -2.478$, $p = .019$; $t(28) = 3.103$, $p = 0.004$ respectively) and inclined high-heeled walking ($t(28) = -3.494$, $p = .002$; $t(28) = 3.476$, $p = .002$ respectively). These results suggest that incline and high-heeled footwear exert substantial mechanical stress on the ankle and tendon, amplifying biomechanical challenges compared to level walking or barefoot conditions.

Table IV: Normalized VGRF, ankle joint force and Achilles tendon force in loaded and unloaded.

Parameters	Variables	Mean ± Standard Deviation		p-value
		Unloaded	Loaded	
VGRF (N/BW)	Level Barefoot	1.04±0.09	1.09±0.11	.076
	Inclined Barefoot	1.01±0.08	1.06±0.13	.184
	Level High-Heeled	1.06 ± 0.11	1.10±0.12	.420
	Incline High-Heeled	1.05±0.13	1.09±0.10	.166
Ankle joint Force (N/BW)	Level Barefoot	0.24±0.09	0.32±0.09	.019*
	Inclined Barefoot	0.58±0.25	0.76±0.30	.092
	Level High-Heeled	0.30±0.05	0.34±0.07	.069
	Incline High-Heeled	1.04±0.30	1.96±0.97	.002*
Archilles Tendon Force (N/BW)	Level Barefoot	-1.25±0.10	-1.39±0.14	.004*
	Inclined Barefoot	-1.53±0.25	-1.74±0.33	.051
	Level High-Heeled	-1.36±0.14	-1.37±0.17	.443
	Incline High-Heeled	-2.02±0.38	-2.98±0.99	.002*

Table V presents the mean and standard deviation values for VGRF, ANK, and FAT forces under level and inclined slope conditions. While no significant differences in VGRF were observed between the conditions, the significant increase in both ANK ($t(28) = -4.913$, $p < .0001$ for barefoot unloaded; $t(28) = -5.382$, $p < .0001$ for barefoot loaded; $t(28) = -9.367$, $p < .0001$ for high-heeled unloaded; $t(28) = -6.445$, $p < .0001$ for high-heeled loaded)and FAT ($t(28) = 3.960$, $p < .0001$ for barefoot unloaded; $t(28) = 3.872$, $p =.001$ for barefoot loaded; $t(28) = 6.697$, $p < .0001$ for high-heeled unloaded and $t(28) = 6.181$, $p < .0001$ for high-heeled loaded) during inclined walking underscores the substantial biomechanical impact of walking on slopes. This finding indicates that inclines impose greater mechanical demands on the ankle and tendon compared to level walking, likely due to the altered kinematics and increased propulsion requirements of uphill gait.

Table V: Normalized VGRF, ankle joint force and Achilles tendon force in different slope conditions.

Parameters	Variables	Mean ± Standard Deviation		p-value
		Level	Inclined	
VGRF (N/BW)	Barefoot unloaded	1.04±0.09	1.01±0.08	.262
	Barefoot loaded	1.09±0.11	1.06±0.13	.303
	High-Heeled unloaded	1.06±0.11	1.05±0.13	.815
	High-Heeled loaded	1.10±0.12	1.09±0.10	.696
Ankle joint Force (N/BW)	Barefoot unloaded	0.24±0.09	0.58±0.25	<.0001*
	Barefoot loaded	0.32±0.09	0.76±0.30	<.0001*
	High-Heeled unloaded	0.30±0.05	1.04±0.30	<.0001*
	High-Heeled loaded	0.34±0.07	1.96±0.97	<.0001*
Archilles Tendon Force (N/BW)	Barefoot unloaded	-1.25±0.10	-1.53±0.25	<.0001*
	Barefoot loaded	-1.36±0.14	-1.74±0.33	.001*
	High-Heeled unloaded	-1.33±0.14	-2.02±0.38	<.0001*
	High-Heeled loaded	-1.37±0.17	-2.98±0.99	<.0001*

DISCUSSION

This study provides an in-depth analysis of VGRF, ANK, and FAT under various walking conditions, including level and inclined walking, barefoot and high-heeled footwear, and loaded versus unloaded scenarios. VGRF provides insights into load distribution and stress patterns that may lead to injuries such as plantar fasciitis or joint degeneration (28). ANK focuses on the loads borne by the ankle joint, helping assess risks such as sprains or chronic instability, particularly in high-stress scenarios like wearing high heels (29). FAT sheds light on the strain experienced by the Achilles tendon, aiding in the prevention of injuries such as tendinopathy or rupture (30).

The findings reveal that walking in high-heeled shoes leads to increase VGRF as shown in Table III. Inclined walking redistributed body weight more vertically, resulting in lower peak VGRF compared to level walking. Hyun et al. (2016) emphasized that high-heeled shoes increase GRF during level walking due to altered gait mechanics and posture adjustments caused by elevated heels. Zeng et al. (2023) further corroborated these findings through a systematic review, noting that high-heeled shoes not only heighten GRF but also disrupt balance and alter lower extremity biomechanics, which collectively increase musculoskeletal stress and injury risk. However, Shang et al. (2020) observed no significant variation in peak GRF across different heel heights during stair ascent, suggesting that dynamic requirements such as step geometry play a more dominant role.

Meanwhile, ANK and FAT forces were significantly higher during inclined walking when wearing high heels compared to barefoot, reflecting the increased mechanical demands placed on the posterior chain. Stefanyshyn et al. (2000) also reported significant alterations in ankle joint forces and gait mechanics due to high-heeled footwear, emphasizing their impact on normal biomechanical function. Furthermore, Luximon et al. (2015) showed that heel height, combined with factors such as slope angle, significantly influences plantar pressure distribution and center of pressure trajectory, contributing to the increased mechanical demands on the ankle joint under inclined conditions. The variation of the center of pressure (COP) increases, requiring higher muscle activation when wearing high-heeled shoes. Wearing high heels results in a shortened position for the calf muscle-tendon unit (MTU). Given the plasticity of muscles and tendons, prolonged use of high heels could potentially lead to alteration in the behaviour of the MTU (34).

Load carriage further amplified these forces, with statistical analysis showing significantly higher ANK and FAT forces during both level barefoot and inclined high-heeled walking under loaded conditions (Table IV). Dames and Smith (2016) reported that load carriage combined with specific footwear significantly influences lower-extremity kinetics. Musculoskeletal injuries in the lower limbs can indeed result from overloading or improper handling of heavy loads. Carrying an additional backpack load increases stress on the skeletal system and may eventually lead to stress fractures, as evidenced by the greater ratio of ANK force increment compared to FAT force decrement during loaded walking (35). Additionally, Lee et al. (2017) noted that uphill walking with a backpack alters gait mechanics, increasing the risk of lower-limb injuries. Walking on level ground or uphill while carrying a backpack can significantly modify gait patterns and elevate the risk of biomechanical strain (36).

The force applied to the ankle joint is significantly higher during inclined walking than during level walking (Table V). In level walking, approximately 80% of the total mechanical work required is performed by the muscles around the ankle joint, with this dependence varying during uphill walking (37-39). Walking on steeper inclines requires a greater amount of positive joint work, with the ankle joint serving as the primary contributor to this positive work, while the increase in negative joint work remains minimal (40). This finding aligns with Montgomery and Grabowski (2018) and Alexander et al. (2017), who observed a marked elevation in lower limb joint work on slopes.

Overall, this study provides valuable insights into how factors such as footwear type, particularly high-heeled shoes, walking conditions, and load carriage influence biomechanical stresses on the lower limbs through the analysis of VGRF, ANK, and FAT forces. High-heeled footwear was found to significantly increase these stresses, particularly under inclined and loaded conditions, heightening the risk of musculoskeletal strain and injury. By identifying these risks, the study informs the development of ergonomic footwear, targeted injury prevention strategies, and effective rehabilitation protocols. These findings have wide-reaching implications for improving musculoskeletal health across diverse populations, including individuals in occupational and clinical settings.

CONCLUSION

While the vertical ground reaction force (VGRF) was higher during level walking compared to inclined walking, the ankle joint and Achilles tendon forces were significantly greater in inclined conditions. These findings underscore the importance of designing safer footwear with moderate heel heights (ideally no more than 1.5–2 inches (3.81 cm – 5.08 cm)) and wider heel bases to reduce localized stress on the ankle and Achilles tendon. Additionally, limiting the weight of carried loads, such as recommending that individuals avoid carrying bags heavier than 10–15% of their body weight, can help reduce stress on the musculoskeletal system. This is especially crucial when navigating inclined surfaces, where the combined effects of high heels and heavy loads can increase injury risks. The significance is particularly evident for high-heel wearers, as these findings highlight the heightened biomechanical stress associated with high heels, which can elevate the risk of musculoskeletal injuries and discomfort. Future research should investigate the long-term effects of different types of footwear on biomechanics across diverse populations, incorporating larger sample sizes to enhance the reliability and generalizability of the findings. This would provide a better understanding of how different footwear types influence gait, joint stress, and muscle activation. Including a wider range of shoe types, such as flat shoes and sneakers, would offer more comprehensive insights into their role in musculoskeletal health and injury prevention. Expanding research in this direction would lead to evidence-based guidelines for reducing foot-related discomfort and minimizing injury risks across different groups and settings.

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REFERENCES

1. Barkema DD, Derrick TR, Martin PE. Heel height affects lower extremity frontal plane joint moments during walking. Gait Posture. 2012;35(3):483-8. doi:10.1016/j.gaitpost.2011.11.013.
2. Speksnijder CM, vd Munckhof RJ, Moonen SA, Walenkamp GH. The higher the heel the higher the forefoot-pressure in ten healthy women. The foot. 2005;15(1):17-21. doi:10.1016/j.foot.2004.10.001.
3. Di Sipio E, Piccinini G, Pecchioli C, Germanotta M, Iacovelli C, Simbolotti C, et al. Walking variations in healthy women wearing high-heeled shoes: Shoe size and heel height effects. Gait Posture. 2018;63:195-201. doi:10.1016/j.gaitpost.2018.04.048.
4. Dames KD, Smith JD. Effects of load carriage and footwear on lower extremity kinetics and kinematics during overground walking. Gait Posture. 2016;50:207-11. doi:10.1016/j.gaitpost.2016.09.012.
5. Wang J, Gillette JC. Carrying asymmetric loads during stair negotiation: Loaded limb stance vs. unloaded limb stance. Gait Posture. 2018;64:213-9. doi:10.1016/j.gaitpost.2018.06.113.
6. Chow DH, Kwok ML, Au-Yang AC, Holmes AD, Cheng JC, Yao FY, et al. The effect of backpack load on the gait of normal adolescent girls. Ergonomics. 2005;48(6):642-56. doi:10.1080/00140130500070921.
7. Lee S, Li JX. Effects of high-heeled shoes and asymmetrical load carrying on lower-extremity kinematics during walking in young women. J Am Podiatr Med Assoc. 2014;104(1):58-65. doi:10.7547/0003-0538-104.1.58.
8. Nguyen LY, Harris KD, Morelli KM, Tsai L-C. Increased knee flexion and varus moments during gait with high-heeled shoes: a systematic review and meta-analysis. Gait Posture. 2021;85:117-25. doi:10.1016/j.gaitpost.2021.01.017.
9. Lee J, Yoon Y-J, Shin CS. The effect of backpack load carriage on the kinetics and kinematics of ankle and knee joints during uphill walking. J Appl Biomech. 2017;33(6):397-405. doi:10.1123/jab.2016-0221.
10. Kellis E, Arampatzi F. Effects of sex and mode of carrying schoolbags on ground reaction forces and temporal characteristics of gait. Journal of Pediatric Orthopaedics B. 2009;18(5):275-82. doi:10.1097/

BPB.0b013e32832d5d3b.
11. Chew KY, Tan YQ, Chan SC, editors. The effects of different high heeled shoes during gait at the kinetic and kinematic impact. IEEE 15th Student Conference on Research and Development (SCOReD); 2017: IEEE. doi:10.1109/SCOReD.2017.8305435.
12. Sharifmoradi K. The Effect of High Heel Shoes on Tibiofemoral and Patellofemoral joint Contact Forces and Muscle Forces. Journal of Ilam University of Medical Sciences 2019;27(2):159-68. doi:10.29252/sjimu.27.2.159.
13. Hong Y, Li J-X, Fong DT-P. Effect of prolonged walking with backpack loads on trunk muscle activity and fatigue in children. J Electromyogr Kinesiol. 2008;18(6):990-6. doi:10.1016/j.jelekin.2007.06.013.
14. Chan SC, Ang KW, Tan YQ, editors. The Effect of Load Carriage While Wearing High Heeled Shoes on Ankle Joint Kinetics During Walking. IEEE Student Conference on Research and Development (SCOReD); 2020: IEEE. doi:10.1109/SCOReD50371.2020.9250996.
15. Sarvestan J, Ataabadi PA, Yazdanbakhsh F, Abbasi S, Abbasi A, Svoboda Z. Lower limb joint angles and their variability during uphill walking. Gait Posture. 2021;90:434-40. doi:10.1016/j.gaitpost.2021.09.195.
16. Strutzenberger G, Leutgeb L, ClauЯen L, Schwameder H. Gait on slopes: Differences in temporo-spatial, kinematic and kinetic gait parameters between walking on a ramp and on a treadmill. Gait Posture. 2022;91:73-8. doi:10.1016/j.gaitpost.2021.09.196.
17. Franz JR, Lyddon NE, Kram R. Mechanical work performed by the individual legs during uphill and downhill walking. The Journal of Strength & Conditioning Research. 2012;45(2):257-62. doi:10.1016/j.jbiomech.2011.10.034.
18. Montgomery JR, Grabowski AM. The contributions of ankle, knee and hip joint work to individual leg work change during uphill and downhill walking over a range of speeds. Royal Society open science 2018;5(8):180550. doi:10.1098/rsos.180550.
19. Hong Y, Li JX. Influence of load and carrying methods on gait phase and ground reactions in children's stair walking. Gait Posture. 2005;22(1):63-8. doi:10.1016/j.gaitpost.2004.07.001.
20. Zeng Z, Liu Y, Hu X, Li P, Wang LJBPH. Effects of high-heeled shoes on lower extremity biomechanics and balance in females: a systematic review and meta-analysis. BMC Public Health. 2023;23(1):726. doi:10.1186/s12889-023-15641-8.
21. Bigouette J, Simon J, Liu K, Docherty CLJJoat. Altered vertical ground reaction forces in participants with chronic ankle instability while running. Journal of athletic training. 2016;51(9):682-7. doi:10.4085/1062-6050-51.11.11.
22. Rabusin CL, Menz HB, McClelland JA, Evans AM, Landorf KB, Malliaras P, et al. Efficacy of heel lifts versus calf muscle eccentric exercise for mid-portion Achilles tendinopathy (the HEALTHY trial): study protocol for a randomised trial. Journal of foot and ankle research. 2019;12:1-12. doi:10.1186/s13047-019-0325-2.
23. Cronin NJ, Barrett RS, Carty CP. Long-term use of high-heeled shoes alters the neuromechanics of human walking. J Appl Physiol. 2012;112(6):1054-8. doi:10.1152/japplphysiol.01402.2011.
24. Ferley DD, Osborn RW, Vukovich MD. The Effects of Uphill Vs. Level-Grade High-Intensity Interval Training on VO2max, Vmax, VLT, and Tmax in Well-Trained Distance Runners. The Journal of Strength & Conditioning Research. 2013;27(6):1549-59. doi:10.1519/JSC.0b013e3182736923.
25. Yan S-h, Zhang K, Tan G-q, Yang J, Liu Z-c. Effects of obesity on dynamic plantar pressure distribution in Chinese prepubescent children during walking. Gait Posture. 2013;37(1):37-42. doi:10.1016/j.gaitpost.2012.05.018.
26. Hof AL. Scaling gait data to body size. Gait Posture. 1996;3(4):222-3. doi:10.1016/0966-6362(95)01057-2.
27. Field A. Discovering statistics using IBM SPSS statistics: sage; 2013.
28. 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. Journal of exercise rehabilitation. 2016;12(5):451. doi:10.12965/jer.1632592.296.
29. Moore JX, Lambert B, Jenkins GP, McGwin Jr G. Epidemiology of high-heel shoe injuries in US women: 2002 to 2012. The Journal of Foot and Ankle Surgery. 2015;54(4):615-9. doi:10.1053/j.jfas.2015.04.008.
30. Diniz P, Pacheco J, Guerra-Pinto F, Pereira H, Ferreira FC, Kerkhoffs GJKS. Sports Traumatology, Arthroscopy. Achilles tendon elongation after acute rupture: is it a problem? A systematic review. Knee Surg Sports Traumatol Arthrosc. 2020;28(12):4011-30. doi:10.1007/s00167-020-06010-8.
31. 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. doi:10.1016/j.gaitpost.2020.07.065.
32. Stefanyshyn DJ, Nigg BM, Fisher V, O'Flynn B, Liu W. The influence of high heeled shoes on kinematics, kinetics, and muscle EMG of normal female gait. J Appl Biomech. 2000;16(3):309-19. doi:10.1123/jab.16.3.309.
33. Luximon Y, Cong Y, Luximon A, Zhang M. Effects of heel base size, walking speed, and slope angle on center of pressure trajectory and plantar pressure when wearing high-heeled shoes. Human movement science. 2015;41:307-19. doi:10.1016/j.humov.2015.04.003.

34. 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.
35. Harman E, Hoon K, Frykman P, Pandorf C. The effects of backpack weight on the biomechanics of load carriage. Army Research Inst Of Environmental Medicine Natick Ma Military Performancediv; 2000. doi:10.21236/ADA377886.
36. Jones BH, Perrotta DM, Canham-Chervak ML, Nee MA, Brundage JF. Injuries in the military: a review and commentary focused on prevention. Am J Prev Med. 2000;18(3):71-84. doi:10.1016/S0749-3797(99)00169-5.
37. Chan SC, Chia JW, Tan YQ, editors. Kinetic and kinematic impacts during level walking, uphill walking, level running and uphill running. IEEE Student Conference on Research and Development (SCOReD); 2018: IEEE. doi: 10.1109/SCORED.2018.8710809.
38. Alexander N, Strutzenberger G, Ameshofer LM, Schwameder H. Lower limb joint work and joint work contribution during downhill and uphill walking at different inclinations. J Biomech. 2017;61:75-80. doi:10.1016/j.jbiomech.2017.07.001.
39. Neves KA, Johnson AW, Hunter I, Myrer JW. Does Achilles tendon cross sectional area differ after downhill, level and uphill running in trained runners? J Sports Sci Med. 2014;13(4):823. https://pmc.ncbi.nlm.nih.gov/articles/PMC4234952/.
40. Walsh GS, Harrison IJEjoss. Gait and neuromuscular dynamics during level and uphill walking carrying military loads. European journal of sport science. 2022;22(9):1364-73. doi:10.1080/17461391.2021.1953154.