

VARUS KNEE TORQUES IN HIGH-HEELED STAIR DESCENT

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INTRODUCTION

Previous gait research has suggested altered knee joint loads in high-heeled shoes may be associated with knee osteoarthritis (OA) [1]. During level ground gait, increased external knee flexor and varus torques (14-26%) have been identified in moderately- to high-heeled footwear [1,2]. The elevated varus loads suggest magnified compressive forces through the medial compartment of the knee joint [3], which is the typical site for knee OA.

High-heeled footwear alters the loads placed on the lower extremities by shifting weight-bearing to the forefoot and moving the center of mass forward. High-heeled footwear is inherently more unstable as the ankle is in a plantarflexed position and reduces the base of support during single-limb support [4,5]. Mediolateral force excursions are less with high-heeled shoes during gait [4]. Therefore, the knee joint may be the compensatory mechanism for stability.

As females attempt to maintain stability in high-heeled footwear, they may experience difficulty while descending stairs [6]. Negotiating stairs is a daily aspect of community ambulation, so high-heel wearers may modify their descent strategy to maintain stability by making adjustments in the frontal and transverse planes.

Previous research determined that wearing high-heeled shoes produced higher torques in the frontal plane for young adults at the hip, knee and ankle than low-heeled shoes when climbing stairs [5]. The purpose of the current project was to determine the effect of high-heeled shoes on frontal plane torques while descending stairs. The expected results were that females would exhibit reduced mediolateral center of pressure (COP) excursions and higher varus knee torques in high-heeled footwear compared to the low-heel footwear.

METHODS

Seven young adult females (age 23.6 ± 5.5 yrs; 1.7 ± 0.1 m; 62.4 ± 10.4 kg) participated in this project. An eight-camera video system (Vicon, Englewood, CO) was used to track 28 reflective markers placed bilaterally on each subject. Landmarks for tracking included: cervicale, acromion, ASIS, PSIS, sacrum, greater trochanter, mid-femur, fibular head, lateral femoral condyles, mid-tibia, medial and lateral malleolus, calcaneus, 5th metatarsal head and great toe. Kinematic data were captured at 160 Hz using Vicon Nexus software.

A three-step wooden stair module without rails (step height = 19 cm; tread depth = 28 cm) was used for this project. Two portable force platforms (AMTI; Watertown, MA) were placed on the second and third tread to collect ground reaction forces. A third platform was located at the base of the module.

Participants performed stair descent in self-selected low-heel footwear (< 2 cm) and high-heeled footwear (avg. 6.9 ± 1.0 cm). The order of performance was balanced across subjects. Participants performed the stair descent task with arms freely moving at their sides. Participants descended the steps at a self-selected pace. Beginning at the top of the staircase, individuals descended three steps to floor level and walked an additional two meters, coming to a stop with their feet side-by-side. Each participant completed two trials leading with the right foot and two trials leading with the left in each type of footwear, for a total of eight trials.

Inverse dynamics was used to calculate joint angles, joint forces and joint torques in three dimensions. Center of pressure variables were also analyzed. Joint torques were normalized for body mass and are reported as Nm/kg.

Right and left side trials were collapsed into “low-heel” and “high-heeled” conditions. A multivariate analysis of variance (MANOVA) was conducted to determine condition differences for kinetic variables and gait speed. Bonferroni correction was utilized for the multiple (10) comparisons; statistical significance was defined at $p < 0.005$.

RESULTS AND DISCUSSION

While descending stairs in high-heeled shoes, participants walked 8% slower compared to low-heel footwear ($p < 0.001$). Participants walked at 0.66 ± 0.06 m/s in low-heel footwear, while in high-heeled shoes individuals moved at 0.61 ± 0.05 m/s. The slower velocity is an effective strategy for maintaining stability in high-heeled footwear.

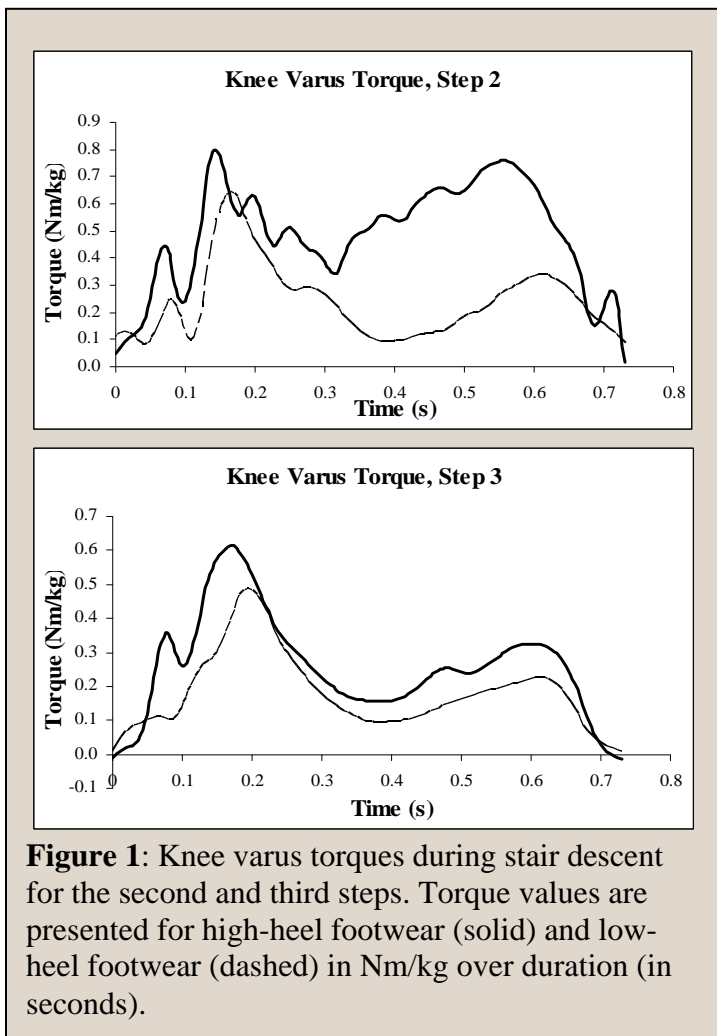


Figure 1: Knee varus torques during stair descent for the second and third steps. Torque values are presented for high-heel footwear (solid) and low-heel footwear (dashed) in Nm/kg over duration (in seconds).

The hypothesis regarding the COP excursion was not supported by the data. The mediolateral COP excursion appeared to be reduced in the high-heeled condition (4.51 ± 1.74 cm) compared to the low-heeled condition (5.72 ± 1.48 cm) on the first step, however the result was not significant ($p = 0.009$)

when the Bonferroni correction was made. The other two steps did not approach statistical significance due to high variability.

The other expected result was supported. Peak knee varus torques were higher in high-heeled footwear than in low-heel footwear (Figure 1) during the stance phase while descending stairs ($p < 0.001$). On the second step, varus knee torque was elevated in high-heeled footwear (0.78 ± 0.19 Nm/kg) compared to low-heel footwear (0.56 ± 0.13 Nm/kg). On the final (or third) step, the high-heeled condition was also higher than the low-heel condition (0.55 ± 0.18 Nm/kg and 0.41 ± 0.08 Nm/kg, respectively.)

Previous researchers have indicated that frontal plane knee torques were higher with high-heeled footwear (0.41 ± 0.23 Nm/kg) compared to low-heel footwear (0.29 ± 0.22 Nm/kg) during stair ascent in young adults [4]. Based on the current findings, it appears varus torques may be higher during stair descent compared to stair ascent.

Stair descent appears to be a task that produces elevated varus torques in females, as values during stair descent in low-heel footwear were higher than reported varus torques (0.39 ± 0.06 Nm/kg) for level ground gait in high-heeled footwear [1]. As females have a higher incidence of medial knee OA, this association may warrant further investigation.

CONCLUSIONS

The current findings suggest descending stairs in high-heeled footwear produces increased varus torques at the knee. Resulting medial compressive forces may potentially increase the risk of knee OA in the medial compartment. Individuals also appear to reduce their velocity of descent to maintain stability in high-heeled footwear.

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