

ANALYSIS OF THE EFFECTS OF STILTS WALKING ON JOINT MOMENTS IN LOW EXTREMITIES

John Z. Wu¹, Sharon S. Chiou, and Christopher S. Pan

Health Effects Laboratory Division, National Institute for Occupational Safety & Health (NIOSH)
Morgantown, West Virginia, USA. ¹E-mail: jwu@cdc.gov



Introduction

Stilts are commonly used at construction sites for many tasks, such as taping and sanding on the ceiling or upper half of a wall (Fig. 1). Some epidemiological studies indicate that the use of stilts may place workers at increased risk for knee injuries or may increase the likelihood of trips and falls (Schneider and Susi, 1994). However, it is not clear whether the use of stilts during walking will increase musculoskeletal loading, thereby increasing the risk of musculoskeletal injuries in the lower limbs. In the present study, we developed an inverse dynamic model of stilts walking to investigate the effects of this activity on the joint moments in the lower limbs.

Methods

The stilts-walking model was developed using the commercial musculoskeletal simulation software AnyBody (version 2.0, AnyBody Technology, Aalborg, Denmark) by modifying its existing three-dimensional gait model (Gait3D). The 3D gait model (Gait3D) includes only the lower body, i.e., two legs and pelvis. The hip, knee, and ankle joints are considered to have 3-DOFs (degree of freedom) (external/internal rotation, abduction/adduction, and extension/flexion), 1-DOF (extension/flexion), and 2-DOFs (plantar/dorsiflexion and eversion/inversion), respectively.

Four healthy construction workers participated in the study. Subjects walked without or with stilts through a 12-meter straight path. When walking on the stilts, the subjects were elevated by 0.61 m from the floor. A total of 18 reflective spherical markers were placed on the lower extremities of the subjects at the anatomical landmarks, as suggested by Vaughan et al. (1999). For the tests with stilts walking, three additional motion markers were placed on each stilt (Fig. 1). The marker kinematics data were collected at a sampling frequency of 60 Hz using a six-camera system (Peak Performance Technologies Inc., Englewood, CO, USA). Two force platforms (Type 9287 and 9287A, Kistler Instrument Corp., Amherst, NY, USA) embedded in the walkway were used to measure ground reaction forces at a sampling frequency of 600 Hz.

The simulations were performed using an inverse dynamic approach. The model was driven by the motion markers; and the ground reaction forces were applied as boundary conditions. The simulations were performed by applying universal joint muscles on each joint. The obtained generalized muscle "force" in the simulations were the joint moments.

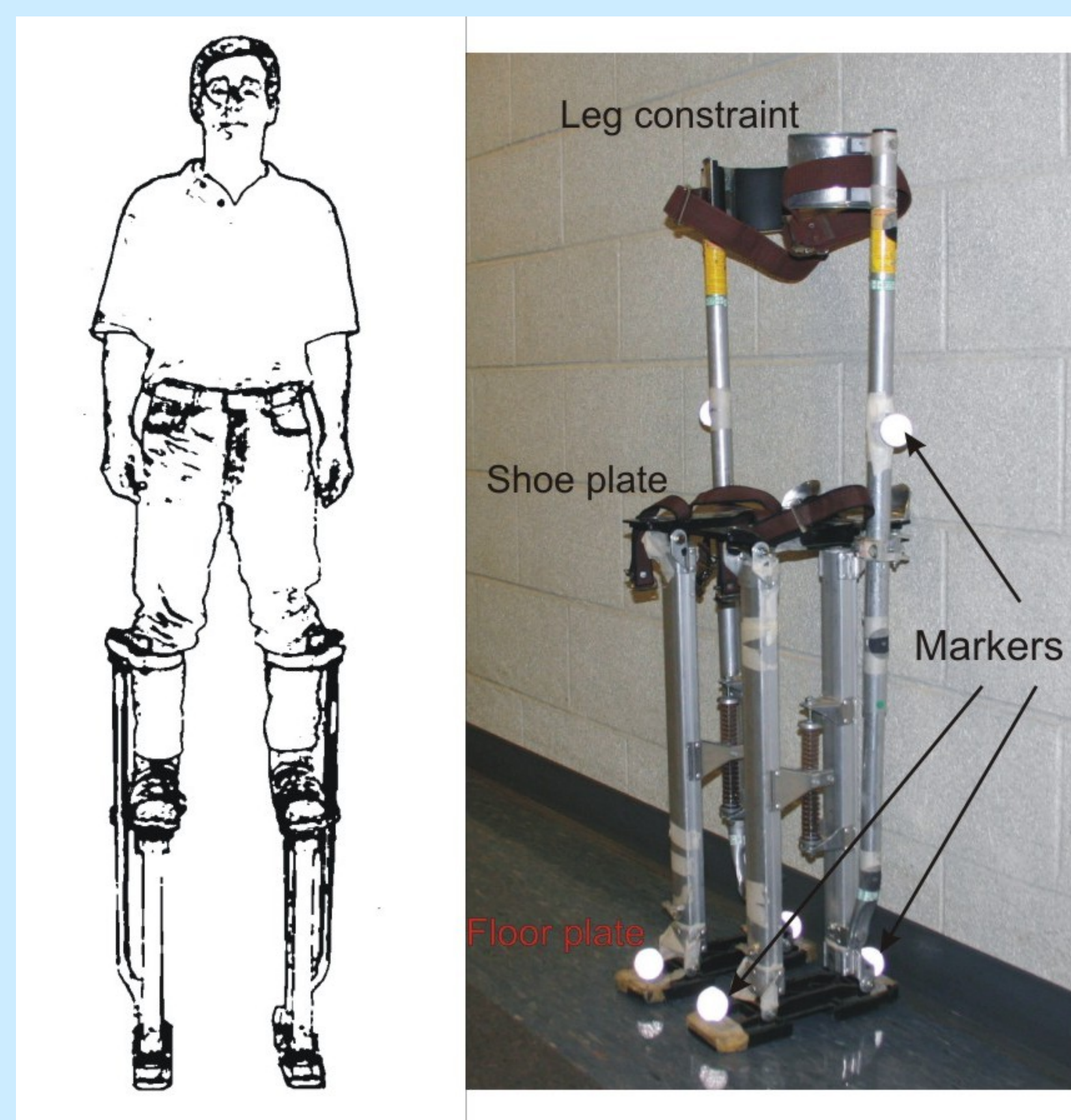


Figure 1: A construction worker walking on stilts (Left). Typical stilts used in construction are made of aluminum (Right).

Results

The predicted time-histories of the joint moments in the sagittal plane for stilts walking are compared with those for normal walk in Fig. 2. The joint moments shown in the figures were normalized by dividing the computed values with the body mass of the subject (in kg). The maximal joint moment was found in the ankle flexional motion and reaches a magnitude of approximately 1.5 Nm/kg at peak. It is seen that the use of stilts caused the peak flexion/extension joint moment to increase by approximately 25% in knee while to decrease by approximately 15% in ankle. The stilts use is found not to cause significant changes of the peak flexional joint moment in the hip.

Discussion

A comparison of the patterns of the joint moment during swing phase indicates that the joint moments for the normal walking become zero immediately after the completion of the walk stance while those for the stilts walking oscillate for one cycle (Fig. 2). These oscillations of the joint moments are caused by the mass inertia effects of the stilts; the legs have to apply extra force to initiate and stop the motion of the stilts at the stance-swing transition and terminal swing, respectively. The mass of a stilt is approximately equivalent to that of a thigh and twice that of a shank (Vaughan et al., 1999).

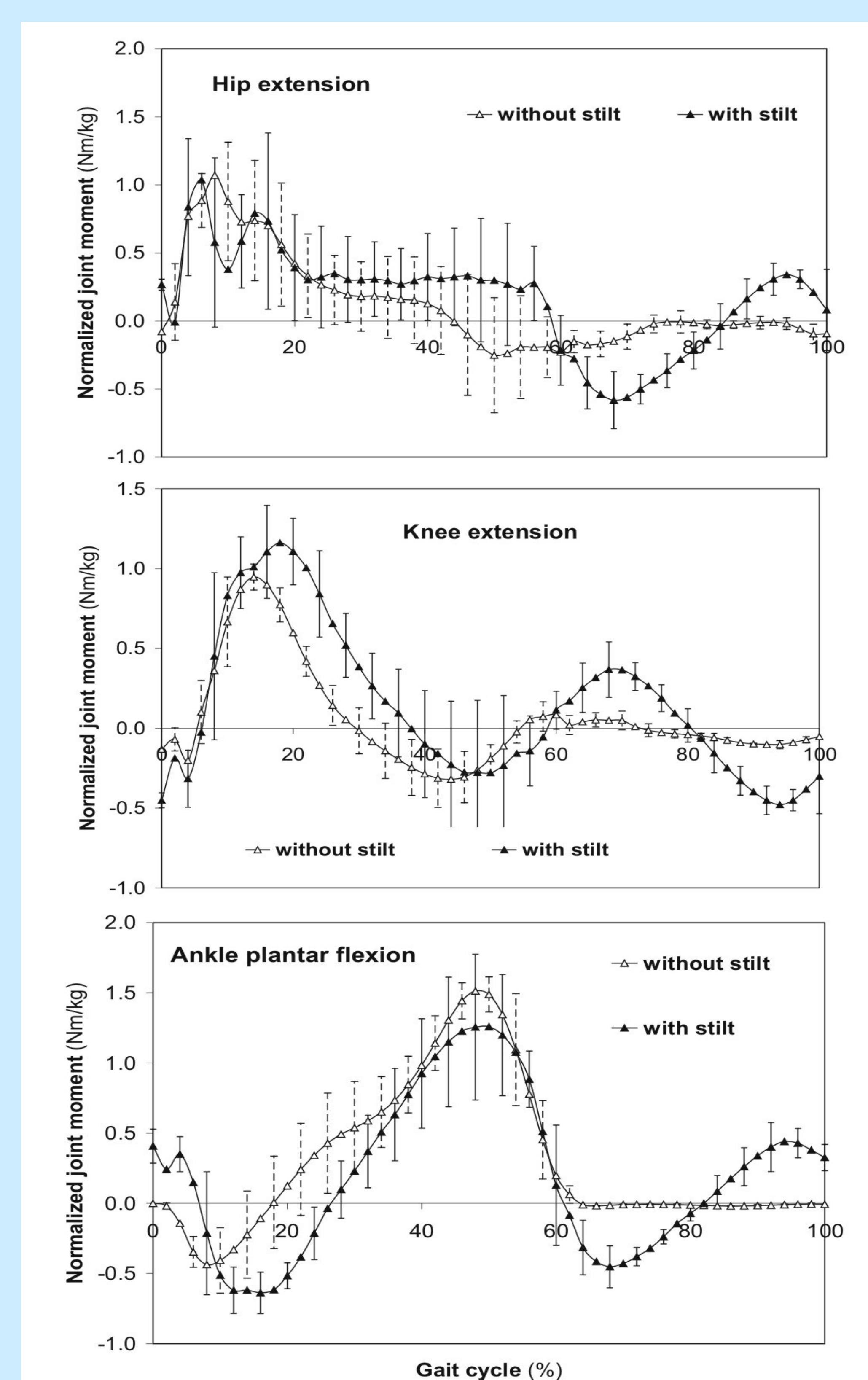


Figure 2: Comparison of the predicted joint moments in hip, knee, and ankle joints for stilts walking with those in normal walking.

Since the mass in the thigh and shank is approximately evenly distributed in a cylindrical section with a length of about 0.4 m, while the mass in the stilt is unevenly distributed in a slim structure with a length of 1.02 m, the mass moments of inertia of a stilt around its lateral axes are estimated to be around ten times those of the thigh and shank.

Conclusion

In the current study, we have analyzed the joint moment and muscle forces in the lower extremities during stilts walking and theoretically evaluated the effects of the stilts use on the joint moments.

References

- Vaughan, C., Davis, B., O'Connor, J. (1999). *Dynamics of Human Gait*. Cape Town, Kiboho Publishers.
- Schneider, S., Susi, P. (1994). *Am Ind Hyg Assoc J*, 55 (7), 635-49.