EFFECTS OF STILTS WALKING ON MUSCULOSKELETAL LOADING IN LOW EXTREMITIES

John Z. Wu*, Sharon S. Chiou, and Christopher S. Pan
National Institute for Occupational Safety and Health
Morgantown, West Virginia, USA. *E-mail: jwu@cdc.gov

INTRODUCTION

Stilts are commonly used at construction sites to raise the workers to a higher level above ground to increase the efficiency for many tasks. 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, no biomechanical analysis has been performed to examine the effects of the stilts walking on the musculoskeletal loading. In the current study, we hypothesize that the use of stilts in walking will increase the musculoskeletal loadings in the lower limbs.

METHODS AND PROCEDURES

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) (Fig. 1). The 3D gait model (Gait3D) includes only the lower body, i.e., two legs and pelvis. The gait model includes a total of 70 muscles -- 35 muscles on each leg. The muscles were simulated by a "classical" three-element muscle model, consisting of a Hill-type contractile element, a parallel elastic element, and a serial elastic element. The recruitment of the muscle forces was calculated by using a min/max optimization procedure in AnyBody, in which the maximal normalized muscle force was minimized. 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.

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. The marker kinematics data were collected at 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 frequency of 600 Hz.

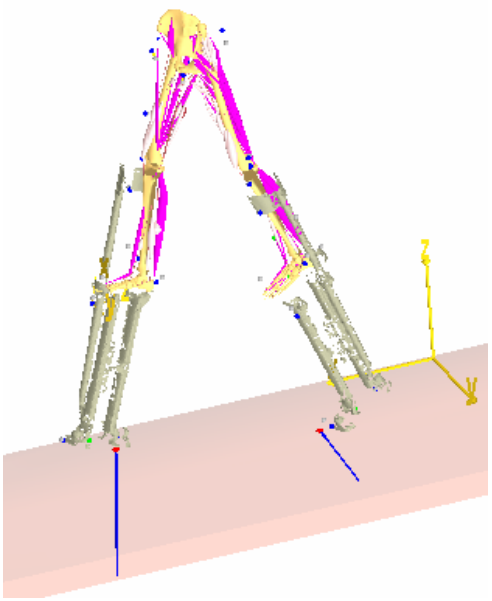

Figure 1: Modeling of stilts walking using commercial software package AnyBody.

RESULTS

The time-histories of the normalized muscle force for eight muscle groups are depicted in Fig. 2. The predicted muscle forces are normalized by their maximal isometric forces in these figures. GAS, GMEDP, and GMEDA muscles are relatively heavily loaded during the normal waling; the peak normalized forces in these muscles are predicted to be around 0.4-0.6. The RF muscle group is least loaded, the normalized muscle force reaches merely 0.16 at peak during the normal walking. The use of stilts induced substantial increases of the peak normalized muscle force in RF and SOL muscles (180% and 35%, respectively). The peak normalized muscle forces in VAS, GMAX, and GMEDA increased by approximately 6%, 9%, and 19%, respectively, due to the stilts use. The peak normalized muscle force in GAS decreased by approximately 49%, while those in HAMS and GMEDP decreased by approximately 29% and 20%, respectively, due to the stilts use.

DISCUSSION

The use of stilts is found to influence force distributions among the muscles. Our simulations indicated that, for the eight muscles groups analyzed, the forces in five muscle groups are increased while those in three muscle groups are decreased due to the stilts use. The increases in muscle loading during the stilts walking may speed the muscle fatigue of the workers, influencing the postural balance.

SUMMARY

Our simulations suggested that the use of stilts may potentially cause an increase in loadings in five of eight major muscle groups in the lower extremities. Most remarkable is the force in RF muscle, which was found to increase 1.8 times for the stilts walking compared to that for the normal walking.

REFERENCES

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Disclaimers

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

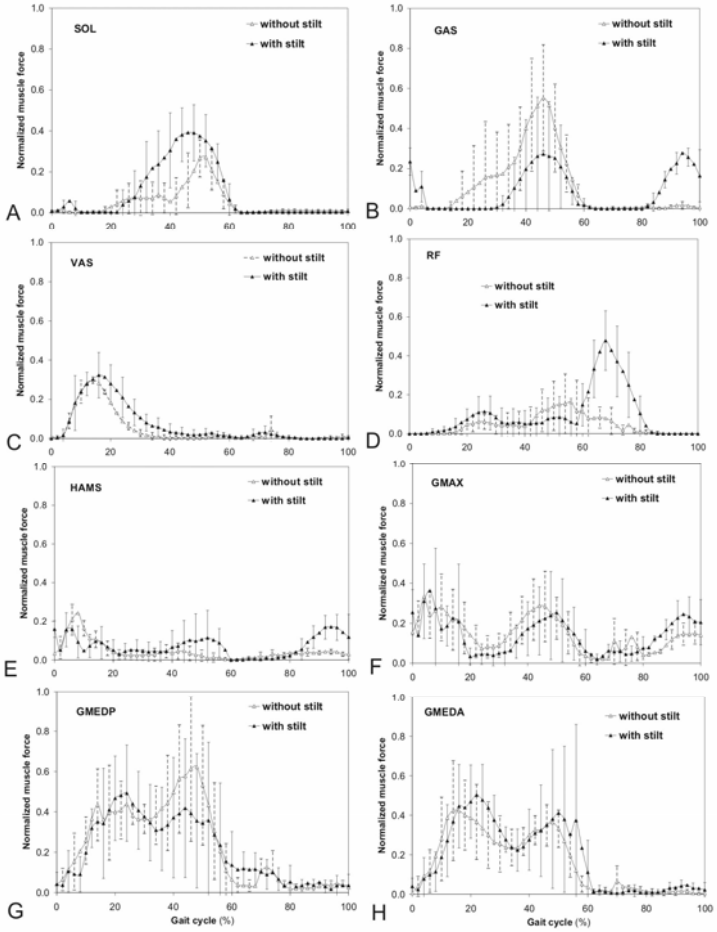

Figure 2: Comparison of the normalized forces in eight muscles or muscle groups for stilts walking with those for normal walking during one gait cycle. A: SOL (soleus), B: GAS (gastrocnemius), C: VAS (vastii: vastus lateralis/medialis/intermedius), D: RF (rectus femoris), E: HAMS (hamstring), F: GMAX (gluteus maximus), G: GMEDP (posterior gluteus minimus/medius), and H: GMEDA (anterior gluteus minimus/medius).