EFFECTS OF OBESITY ON THE BIOMECHANICS OF UPHILL WALKING

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INTRODUCTION

Walking is a popular form of exercise for the prevention and treatment of obesity. However, walking may be a source of biomechanical loads that link obesity and musculoskeletal injury and pathology, including knee osteoarthritis [4]. During level walking, moderately obese adults have greater lower extremity net muscle moments (Nm) vs. their non-obese counterparts [1,2]. During uphill walking at the same speed, hip and knee extensor moments are greater than during level walking in non-obese adults [3]. In addition, biarticular hip extensor/knee flexor muscle activity increases during uphill vs. level walking, suggesting that net muscle moments may underestimate knee joint loading when individuals walk uphill [3]. The effects of obesity on lower extremity kinematics, kinetics and muscle activation during uphill vs. level walking are not known. Thus, the relationship between net muscle moments and joint loading in obese adults has not been established. A comprehensive understanding of how gradients affect the biomechanics of walking in obese adults may aid in the development of exercise recommendations that provide adequate cardiovascular stimulus while reducing the risk of musculoskeletal pathology.

The purpose of this study was to quantify the biomechanics of uphill vs. level walking in moderately obese vs. non-obese adults. We hypothesized that hip and knee extensor moments (Nm/kg) and muscle activity would increase during uphill vs. level walking in both groups with no between group differences.

METHODS

Fifteen obese, 105.5 (16.7) kg, 35.0 (4.5) kg/m², (mean (SD)) and thirteen non-obese, 64.4 (10.6) kg, 21.6 (2.0) kg/m² adult volunteers participated in this study. We measured ground reaction forces, three-dimensional lower extremity kinematics and EMG of five lower extremity muscles (Biceps Femoris (BF), Semimembranosus (SM), Vastus Lateralis (VL), Vastus Medialis (VM) and Lateral Gastrocnemius (GAST)) while subjects walked on a dual-belt force measuring treadmill at 1.25 m/s. Each subject completed 2 or 6 minute trials with the treadmill grade set at 0, 3, 6 and 9°, with 30 seconds of biomechanics data collected during the final minute of the trial. Kinematic parameters were recorded at 100 Hz using seven optoelectric cameras. Ground reaction forces and moments were recorded at 1000 Hz by force platforms embedded under each treadmill belt and EMG data were recorded at 2000 Hz via surface electrodes placed over each muscle. Body segment parameters were estimated via DEXA and published regression equations [5]. We calculated net muscle moments and powers at the hip, knee and ankle via standard inverse dynamics techniques after adjusting for markers placed over adipose tissue. We also determined the timing, duration and mean EMG amplitude of each muscle and normalized these variables to the level walking condition. We calculated the mean of each variable of interest over 10-25 strides at each grade for each subject and the mean across subjects for each trial.

A two-factor (obesity and grade) repeated-measures ANOVA determined how obesity affected kinematic, kinetic and EMG variables. Necessary post-hoc comparisons using Holm-Sidak were performed. A criterion of p<0.05 defined significance.

RESULTS AND DISCUSSION

Obese adults had a greater step width and longer period of double support compared to non-obese adults. There were no significant temporal-spatial differences measured in uphill vs. level walking, (i.e. stride length and stride frequency were similar).
Participants walked uphill with a more flexed posture, characterized by greater knee and hip flexion.

Both groups exhibited increased hip extensor and flexor net muscle moments when walking uphill vs. level walking (Fig. 1). Hip extensor angular impulse was much greater in obese vs. non-obese participants at all gradients (p<0.001). Peak knee extensor moments were smaller during uphill vs. level walking in obese but similar in non-obese across the gradients. Ankle plantarflexor moments increased with grade and were smaller in obese vs. non-obese individuals. EMG amplitude was greater during uphill vs. level walking in both groups (Fig. 2), but there were no differences between groups. SM and BF amplitudes increased much more than the VL, VM and GAST. EMG duration was also greater during uphill vs. level walking in all muscles. As a result, there was greater co-activation of knee flexors and extensors during early stance, coincident with the peak knee extensor moment.

These results suggest that obese and non-obese adults walk uphill using a similar strategy that relies more on the hip extensor muscles than during level walking. This strategy results in significant increases in EMG activity and co-contraction of the muscles that cross the knee joint, likely resulting in increased knee joint loading during stance. Thus, while knee net muscle moments decrease in obese adults during uphill vs. level walking at the same speed, this may not be associated with reduced knee joint loads.

**REFERENCES**

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