INTRODUCTION

Brisk walking is a recommended form of exercise for obese individuals. However, walking may be a source of biomechanical loads that link obesity and musculoskeletal injury and pathology, including knee osteoarthritis [1]. In obese adults, lower extremity joint loads and the associated risk of musculoskeletal injury or pathology increase with walking speed on level ground [2], but these individuals may walk with a more extended leg to reduce knee joint loads [3]. Walking uphill at a slower speed may be an alternative form of moderate intensity exercise that reduces joint loading. During uphill walking at the same speed, hip and knee extensor moments are greater than during level walking in non-obese adults [4] but may be smaller in obese adults when walking at a slower speed. To date, no study has compared the energetics and biomechanics of obese and non-obese adults during faster level vs. slower walking. A comprehensive understanding of how obesity and gradients affect the energetics and biomechanics of walking may aid in the development of exercise recommendations that provide adequate physiologic stimulus while reducing the risk of musculoskeletal pathology.

The purpose of this study was to quantify the energetics and biomechanics of level vs. uphill walking in moderately obese vs. non-obese adults. We hypothesized that metabolic rate would be similar while net muscle moments would be smaller during slow, uphill vs. fast, level walking and that there would be no differences between groups.

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 metabolic rate, ground reaction forces, three-dimensional lower extremity kinematics while subjects walked for 6 minutes on a dual-belt force measuring treadmill at 1.50 m/s (0°) and 0.75 m/s (6°). Metabolic data was measured continuously via a portable indirect calorimetry system while 30 seconds of biomechanics data was collected during the final minute of the each trial. Kinematic parameters were recorded at 100 Hz using a 7-camera motion capture system. Ground reaction forces and moments were recorded at 1000 Hz by force platforms embedded under each treadmill belt. Body segment parameters were estimated via DEXA and published regression equations [5]. Lower extremity joint centers were determined after adjusting for markers placed over adipose tissue. We calculated gross and net metabolic rate (W/kg) and metabolic cost (J/kg/m) and net muscle moments and powers at the hip, knee and ankle. 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 metabolic, kinematic, and kinetic variables. Necessary post-hoc comparisons using Holm-Sidak were performed. A criterion of p<0.05 defined significance.

RESULTS AND DISCUSSION

Net metabolic rate (gross-standing) was similar during the two walking trials and between groups. When walking at 1.50 m/s, net metabolic rate was 3.74 (0.11) vs. 3.41 (0.21) (mean (SE)) W/kg for the obese and non-obese, respectively. During uphill walking, net metabolic rate was 3.91 (0.06) vs. 4.11 (0.09) W/kg for the obese and non-obese, respectively.
Both groups adjusted temporal-spatial parameters during uphill vs. level walking, as would be expected based on the change in walking speed. At both speed/grade combinations, the obese participants walked with wider steps, shorter strides and spent more time in double support compared to the non-obese participants.

Both groups walked uphill with a more flexed posture, characterized by greater knee and hip flexion. Peak net muscle moments were smaller during uphill vs. level walking in both groups and peak knee net muscle moments were smaller in obese vs. non-obese adults. As a result, hip joint positive power was much greater during uphill vs. level walking (Figure 1). In addition, knee joint negative power during early stance in obese adults was smaller compared to non-obese adults.

Obese adults performed much more net hip joint work during level and uphill walking compared to non-obese adults. Positive knee joint work was greater during level walking and obese individuals performed much less negative knee joint work compared to non-obese individuals, particularly during early and late stance. Ankle joint work was similar when walking uphill vs. level walking but obese adults performed less net work compared to non-obese adults.

CONCLUSIONS

These results suggest that slow uphill vs. faster, level walking requires greater net hip joint work in obese but greater net knee joint work in non-obese adults. Thus, different gait strategies result in similar net metabolic rates.

REFERENCES


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