LOWER EXTREMITY COORDINATION IN OBESE WOMEN

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INTRODUCTION

There exists a relationship among the timings of lower extremity segments and pathology. Lower extremity coupling/interaction patterns between the rearfoot and leg may have implications for injury at the knee joint. Rearfoot eversion can alter the kinematics and kinetics farther up the chain in the lower extremity and possibly risk injury to bone and/or soft tissue. Obese persons have greater rearfoot eversion ranges of motion than non-obese [1]. Examining the coordinated motion of the lower extremity segments in space and time gives insights that traditional time series plots of joint angles cannot. Obesity is also the primary, modifiable risk factor for soft tissue knee injuries such as osteoarthritis [2] and it is possible that the coupling relationships between the rearfoot and leg may be related to this soft tissue injury.

Pohl et al. [3] investigated these coordination relationships in walking and found that prolonged tibia external rotation occurred as the rearfoot began to invert. These opposing motions between the articulating rearfoot and leg segments may differ between obese and non-obese individuals and have important implications for lower extremity injury. The purpose of this study was to explore inter-limb kinematic coordination in obese women. We hypothesized that greater eversion range of motion in the obese group would alter the rearfoot-leg coordination patterns between obese and non-obese.

METHODS

Ten obese (age 25.3 ± 9.8 years; BMI 33.09 kgm^{-2}) and ten non-obese (age 25.1 ± 3.8; BMI 22.66 kgm^{-2}) women gave written consent to participate in the study. All participants were free of injuries.

Kinematic (240 Hz) and ground reaction force (1200 Hz) data were collected as subjects walked at a self-selected pace ten times across a force platform. Kinematic data were low-pass filtered and interpolated to 101 data points. Rearfoot eversion/inversion and leg rotation segment angles were calculated in the global coordinate system. All angles were referenced to a standing posture.

A modified vector coding approach assessed the coordination between the segments. Angle-angle plots of the leg relative to the rearfoot were constructed and inter-segment coordination was inferred from the vector angle (θ) between two adjacent time points relative to the horizontal.

$$\theta_i = \left| \tan^{-1}[(y_{i+1}-y_i)/(x_{i+1}-x_i)] \right|$$

Vector angles of 45° and 135° indicated in-phase and anti-phase coordination, respectively. Angles of 90° and 0°/180° indicate exclusively rearfoot and leg movement, respectively. Vector angles were averaged using circular statistics across each third of stance. Rearfoot and leg ranges of motion were the difference between max and minimum values.

To examine continuous inter-limb coordination between segments rotations, zero-lag cross correlations were calculated across time series angular displacement curves. Fisher's Z-Transformation was applied to these values for statistical analyses. Multi-variate ANOVA's ($p<0.05$) assessed differences between groups and tertiles of stance and effect sizes (ES) assessed differences between groups.

RESULTS

The obese group walked significantly slower than the non-obese group (1.33±0.08 vs.1.46±0.12 m·s^{-1}) ($p=0.017$) by decreasing step length (0.75±0.1 vs. 0.80±0.1 m) and frequency (106.6±4.8 vs. 109.7±4.4 steps/s).

Range of motion was greater in the obese group for the rearfoot (13.1^{o}±4.2 vs. 10.5^{o}±2.6; $p<0.01$) and leg (19.3^{o}±4.9 vs. 16.9^{o}±4.2; $p<0.01$) (Fig. 1). Foot eversion occurred with leg internal rotation in early stance and external rotation in late stance.

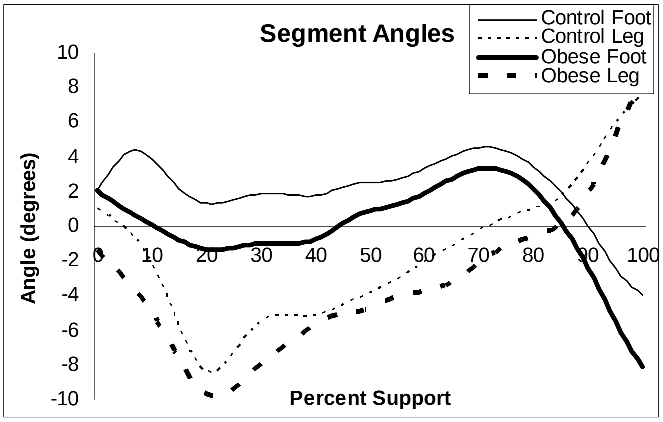

Figure 1: Rearfoot inversion (+)/eversion (-) and leg external (+)/internal (-) rotation.

Cross correlations were low except during late stance when large opposing rotations of rearfoot eversion and leg external rotation occurred (Table 1).

Table 1. Cross correlations between rearfoot and leg excursions. In both tables, * indicates significant differences between groups and numbers indicate significant differences from other tertiles of stance.

	Early stance	Mid stance	Late stance
Control	0.44±0.54 ^{3}	0.36±0.61 ^{3}	-0.76±0.53 ^{1,2}
Obese	0.34±0.62 ^{3}	0.29±0.55 ^{3}	-0.91±0.11 ^{1,2}

Across the stance phase, the vector coding showed no differences between the obese and control coordination patterns (p=0.742, ES=0.48), but there were differences between the groups at mid stance (Table 2, Fig 2).

Table 2: Vector coding analysis of coordination patterns between the foot and leg.

	Early stance ES = 0.32	Mid stance ES = 0.75	Late stance ES = 0.04
Control	37.17° ^{3}	28.14° * ^{3}	117.41° ^{1,2}
Obese	22.30° ^{2,3}	44.99° * ^{1,3}	117.71° ^{1,2}

CONCLUSION

The combination of increased rearfoot and leg range of motion in the obese group altered the coordination patterns between the groups, despite similar shapes of segment angle plots. Large negative correlations for the opposing rotations of the rearfoot and leg in late stance suggest that the strongest temporal, coupled coordination occurs before toe-off.

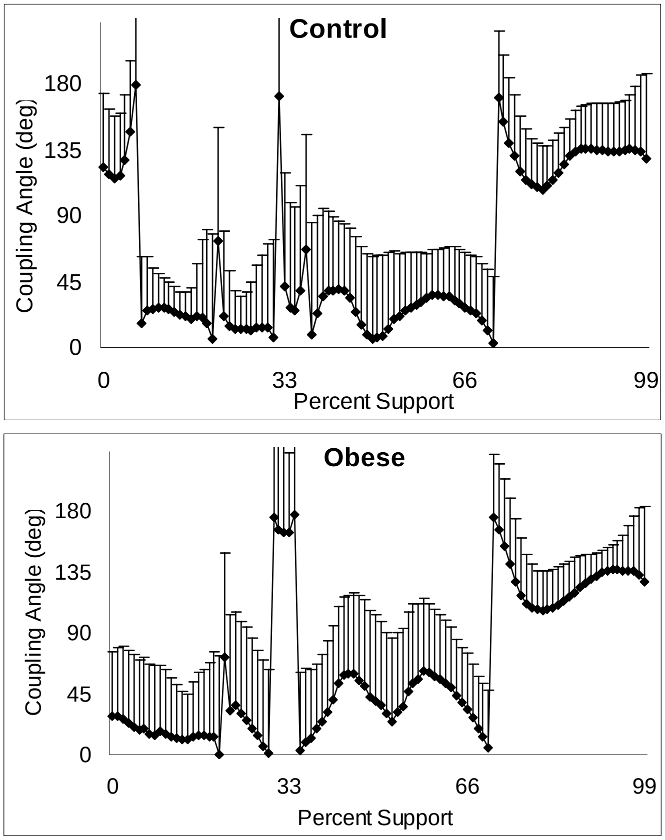

Figure 2: Mean vector coding angles and standard deviation bars

The vector coding approach gives a more detailed assessment of the coordination. Overall, during early stance, the foot eversion with leg internal rotation produced a moderately in-phase coordination of the two segments, however the control group showed greater inversion during early stance. During mid-stance the obese group displayed in-phase coordination while the control group had greater proximal segment motion. During late stance, a more anti-phase coordination pattern predominated between the rearfoot and leg. Asynchronous timing between these segments may be a risk factor for chronic lower-extremity injury [4]. These opposing motions may place stress on soft tissue and have detrimental impact on the tissue and ligaments at the ankle and superior joints.

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