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KNEE BIOMECHANICS DURING CYCLING ARE SIMILAR FOR NORMAL WEIGHT AND OBESE SUBJECTS

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INTRODUCTION

Osteoarthritis (OA) is a degenerative disease of cartilage and bone tissue, and is linked to more than 70% of total hip and knee replacements [1]. In 1994 the direct and indirect costs of OA in the United States were $155 billion [2] and in 2006 OA resulted in approximately $10.5 billion in hospital charges [3]. Obesity is a risk factor for OA [1, 3, 4], likely due to increased knee loading [5, 6] and varus malalignment [7] in gait. Seated cycling has been recommended as a weight-loss exercise with lower knee loads than walking or jogging [8]. However, lack of biomechanical studies for obese subjects in exercises, other than gait, impedes selection of exercises that may best prevent knee OA development in the obese population.

This study tests the hypothesis that cycling knee kinematics and kinetics are not different for normal weight (NW) and obese (OB) subjects. The long-term goal of our research group is to calculate knee joint loading and kinematics during select exercises to aid in selection of weight-loss exercises that minimize risk of OA development. The objectives of this study are to (1) conduct cycling experiments with a motion capture system to calculate internal knee kinematics and kinetics and (2) compare knee kinematics and kinetics for normal weight and obese subjects during cycling.

METHODS

Bicycle Development. The pedals in an upright stationary bicycle (LifeFitness LifeCycle GX, Rosemont, IL, USA) were modified to include 6-channel load cells (GEN5, AMTI, Watertown, MA, USA) [9] (Fig. 1). The pedals included a marker set for use with a motion capture system to track crank angle.

Subject Selection. Subjects were separated into two populations, NW (n=4) and OB (n=4), determined by body mass index (BMI). Protocols were approved by Cal Poly's Human Subjects Committee to minimize risks to human subjects.

Experimental Procedure. Retroreflective markers were placed on subjects using a lower body Helen Hayes marker set. An eight-camera motion capture system and Cortex software (Motion Analysis, Santa Rosa, CA, USA) were used to record marker position and process kinematic data. Subjects stood motionless for a static trial to create virtual axes for body segments. The dominant and non-dominant legs for each subject were identified. Subjects pedaled the modified bicycle with a cadence of 70 RPM at low (C1) and moderate (C2) intensities, measured using the bicycle's resistance levels, for 2 minutes after reaching a steady cadence. Kinematic and kinetic data collected were processed in Cortex. Custom MATLAB (MathWorks, Natick, MA, USA) codes were used to format and average data for three crank cycles. Knee angles were corrected for crosstalk error using custom code with Principal Component Analysis (PCA) [9]; briefly, PCA minimizes the flexion-adduction correlation (R^2) value that is considered a quantitative measure of crosstalk caused by error in flexion axis direction. Only absolute magnitude values are reported here.

Fig. 1: Subject pedaling bicycle with custom instrumented pedals.

Statistical Analysis. Three-way repeated measures ANOVAs, followed by Tukey pairwise comparisons, were performed to determine differences in knee forces, moments, and angles using BMI, cycling intensity, and leg dominance as factors. Statistical significance was defined by $p<0.05$. Interactions between BMI, intensity, and leg dominance were considered, as well as differences within each factor alone.

RESULTS

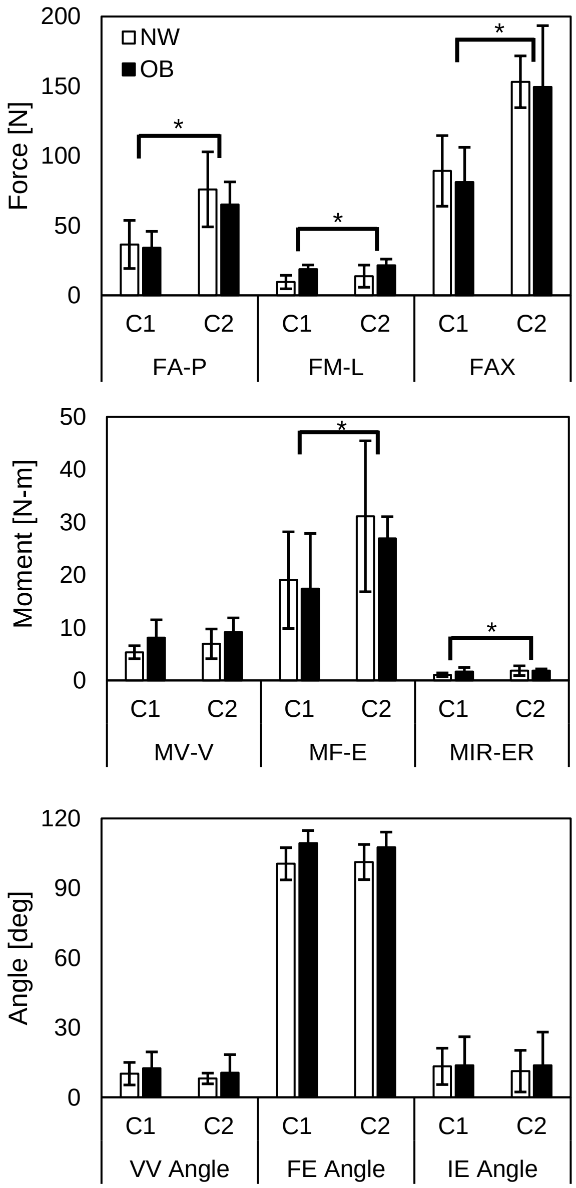

Fig. 2: Knee biomechanics during low (C1) and moderate (C2) cycling intensities for NW and OB subjects. Dominant leg shown. FA-P, FM-L, and FA-X represent anterior-posterior, medial-lateral, and axial knee forces. MV-V, MF-E, and MIR-ER represent varus-valgus, flexion-extension, and internal-external rotation moments. V-V, F-E, and IR-ER Angles represent varus-valgus, flexion-extension, and internal-external rotation knee angles. *Significant difference due to intensity ($p<0.05$).

Knee loads did not differ for NW and OB subjects, expect when comparing cycling intensity levels (C1 and C2) (Fig 2). For all statistically significant cases, C2 had higher loads than C1 ($p=0.006$ for FA-P, $p=0.034$ for FM-L, $p<0.001$ for FAX, $p=0.016$ for MF-E, $p=0.005$ for MIR-ER). All other results showed statistical similarities for knee kinematics and kinetics in cycling between NW and OB subjects. PCA reduced the knee flexion-adduction angle correlations measured using R^2 values which were decreased by three orders of magnitude, thus showing a decrease in knee angle cross-talk.

DISCUSSION

All knee forces and the axial and flexion-extension moments for moderate cycling intensity (C2) were higher than low intensity cycling (C1). This is expected as the higher intensity with constant cadence causes the cycling effort to increase. Knee loading and kinematics were similar for BMI, leg dominance, and their interaction. This is beneficial as similar knee loads are seen in OB and NW subjects during cycling, which could translate to substantially lower OB knee loads in cycling as compared to gait.

The varus-valgus moment does not show statistical significance for any of the tests performed. This result suggests that cycling could minimize the effects of varus misalignment linked to gait in OB subjects. Thus, these results suggest that cycling, likely due to its status as a non-weight bearing exercise, may be a preferred weight-loss exercise as knee loads are not increased due to BMI as occurs in full weight-bearing exercises such as gait [4, 6].

This study has several limitations. First, the sample size was relatively low. Although a power study performed indicates as few as 14 subjects per subject population (NW and OB) could highlight more significant differences due to BMI, the measured knee loads for cycling are substantially lower than previous results for gait [4-6]. Second, soft tissue artifact (STA) (skin and adipose tissue moving around bone tissue causing marker position to differ from bone position) likely produced errors in knee angles. Third, this study reported resultant loads, which differ from the joint contact force that is the true load seen by articular cartilage tissue. Our ongoing cycling studies are using algorithms to minimize STA and employing EMG-driven inverse dynamics to calculate knee contact loads. Regardless, this study produced novel comparisons of knee biomechanics during cycling for NW and OB subjects that suggest that non-weight bearing exercises, such as cycling, should be recommended in weight-loss programs.

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