HOW OBESITY AFFECTS HIP JOINT CONTACT FORCES DURING WALKING IN CHILDREN

Raymond C. Browning and Zachary F. Lerner

Colorado State University, Fort Collins, CO, USA
email: Zach.Lerner@ColoState.edu web: http://pal.colostate.edu

INTRODUCTION

Obese children are at an increased risk of developing orthopedic disorders of the lower-extremity. At the hip, a strong, positive association exists between pediatric obesity and a reduction in femoral neck anteversion angle and slipped capitol femoral epiphysis (SCFE), the most common hip disorder in children [1, 2]. SCFE is a debilitating condition that results in an inferior-posterior slip of the femoral head relative to the femoral neck along the physis. It has been theorized that altered hip joint loading during daily physical activity (e.g. walking) in obese children may contribute to their increased risk of developing these orthopaedic disorders of the hip [1, 2]. However, it remains unknown how pediatric obesity affects hip joint loads during walking. This gap in the literature limits our ability to evaluate the risk-benefit ratio of walking physical activity on the musculoskeletal system of obese children. This study sought to determine the effects of pediatric obesity on compressive and shear hip joint contact forces and loading rates during walking.

METHODS

Kinematic and kinetic data was collected during treadmill walking at 1 m•s\(^{-1}\) in 10 obese (BMI\(_z\) > 95%) and 10 healthy-weight (5% < BMI\(_z\) < 85%) 8-12 year-olds. Age, sex, and leg length were similar between groups. We used dual x-ray absorptiometry (DXA) to determine body composition, segment masses, lower-extremity alignment, and femoral neck angle (Fig. 1) and width for each child.

To validate our musculoskeletal model and optimization scheme used to predict muscle forces, we compared measured to predicted axial, mediolateral, and anterioposterior hip joint contact forces for an individual with an instrumented hip prosthesis walking at 1.08 m•s\(^{-1}\) [3]. Predicted loads had similar magnitudes and waveforms. At peak loading, which occurred during early-mid stance, peak axial, anterioposterior, and mediolateral contact force predictions had accuracies of 98.6%, 90.3%, and 85.7%, respectively.

We scaled a generic OpenSim musculoskeletal model to the size of each participant and subsequently specified lower-extremity alignment and segment masses to create a subject-specific model for each child. We used a weighted static optimization approach to estimate the muscle forces that reproduced the measured walking mechanics determined from inverse dynamics, and calculated hip joint contact forces using the joint reaction analysis [4]. To compute compressive and shear forces, we transformed the contact forces from the reference frame of the hip to that of each child’s femoral neck (Fig. 1).

Figure 1: Measurement of femoral neck angle (θ) from a representative participant’s DXA radiograph (inset) and transformation of the hip joint contact forces.
RESULTS AND DISCUSSION

Obesity affected compressive and shear hip joint loading (Fig. 2). First peak compressive contact forces (N) during stance were 1.8 times greater in the obese vs. healthy-weight participants ($p<0.001$). Similarly, first peak distal and posterior shear forces were 1.8 and 1.5 times greater ($p<0.001$), respectively, in the obese vs. healthy-weight children.

![Figure 2](image)

**Figure 2:** Compressive (top), vertical shear (middle), and anterioposterior shear (bottom) hip joint contact forces in obese (red, solid) and healthy-weight (blue, dashed) children.

Peak compressive and resultant shear loading rates, which occurred during early stance, were 1.47 times (10.15 vs. 6.89 kN•s$^{-1}$, $p<0.001$) and 1.43 times (4.35 vs. 3.03 kN•s$^{-1}$, $p=0.002$) greater in the obese vs. healthy-weight participants, respectively.

The hip joint contact force load vectors had similar directions but greater magnitudes in both the sagittal and transverse planes for the obese vs. healthy-weight children (Fig. 3). The directions of the applied shear forces (inferior and posterior) are consistent with the direction of femoral head slippage in the SCFE condition (inferior-posterior).

![Figure 3](image)

**Figure 3:** First peak hip contact force load vectors in the sagittal (left) and transverse (right) planes for the obese (red, solid) and healthy-weight (blue, dashed) children.

CONCLUSIONS

Our results of greater compressive and shear forces at the hip during walking in obese children provides biomechanical evidence that altered loading during daily walking physical activity may contribute to their increased risk of developing orthopaedic disorders at the hip. Femoral neck diameter was similar between groups. This suggests that our findings of greater contact forces in the obese children likely represent similarly elevated compressive and shear stresses at the growth-plate. The results of this study may help clinicians weigh the risk-benefit ratio of increased physical activity on the musculoskeletal system in obese children.

REFERENCES


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