ABDUCTOR AND ANTAGONIST MUSCLE FORCE DISTRIBUTIONS SUBSTANTIALLY INFLUENCE MODELED HIP FORCES IN SUBJECTS WITH TOTAL HIP REPLACEMENTS

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Introduction: The use of total hip replacements (THR) in younger, more active patients raises new questions regarding the influence of gait mechanics on mechanical implant failure. Physiologically it is possible to use a broad range of muscle forces during walking. This non-deterministic nature of walking allows the neuromuscular system to adapt to a variety of conditions. A previously published analytical model (1) is ideally suited for examining the effect of muscle force distributions on the hip joint loads. This parametric model predicts a wide range of physiologically based muscle and hip joint forces during gait based on subject-specific joint kinematics and kinetics. Abductor function following THR surgery is an important clinical concern (2) and antagonistic muscle activity clearly increases the hip joint force but by how much is not known. The present study assesses the sensitivity of the peak hip contact forces to the activation levels of the abductor and antagonist muscles in a group of subjects with THRs.

Methods: The parametric model predicts the hip contact force during gait (1). The external moments, intersegmental forces and joint angles, as calculated during gait analysis, are input to the model along with the maximum isometric moment generating capacity of the muscles (3). Physiologically feasible muscle forces that generate a moment equal and opposite to the external moments are calculated at specified levels of antagonistic muscle activity. At each time point, a full range of agonist muscle force distributions is generated by parametrically varying the moment generating capacity of selected agonist muscles, while keeping the remaining muscles at their original strength. Force solutions are therefore determined over the full range of physiologically possible activation levels for each muscle and for selected functional groups of muscles.

Hip forces were modeled for 17 THR subjects (15 ± 3 months postoperative) while walking (1.02 ± 0.08 m/s). Internal review board approval and informed consent were obtained. The sensitivity of the parametric hip joint forces to the level of abductor and antagonist muscle activity was evaluated at the two peak forces. For each subject, a Pearson correlation coefficient between the peak hip forces and the activation levels of either the abductor or antagonist muscle groups was calculated. Tests were used to determine whether the correlation coefficients of the group were significantly different from zero. The slope of the regression line between the contact force and the antagonist muscle activity was calculated for each subject. The average slope for the group was calculated to assess how much the contact force changed for a given change in the antagonistic activation level.

Results: The abductor activity level predicted 47% of the variability in the second peak force (R² = 0.49 ± 0.32, p < 0.001) but was not predictive of the first peak force (p = 0.15). For the representative subject shown in Figure 1, variations in the abductor activation level resulted in the second peak force varying from 2.7 to 3.2 Body Weights (BW). For the entire group, physiological variations in these muscle distributions resulted in the first peak force changing by 18 ± 7% and the second peak force, by 26 ± 7%. For the group, there was a significant correlation between the antagonist muscle activity and both peak forces (first peak: R² = 0.89 ± 0.18, p < 0.001; second peak: R² = 0.89 ± 0.10, p < 0.001). A 10% increase in antagonistic muscle activity resulted in a 0.3 BW increase in the first peak force and a 0.4 BW increase in the second peak force. Figure 2 shows the effect of increased antagonist activity on the range of modeled contact forces throughout stance for the representative subject.

Discussion: Modeled hip forces during gait were highly sensitive to both the abductor and antagonist activation levels. As much as a 26% increase in contact force resulted from physiological variations in abductor muscle forces. Increasing the antagonist activation level by 10% raised the contact force by as much as 0.4 BW. The abductors play an important role in maintaining upright posture during walking, and are the most likely muscles to be compromised during THR surgery. An awareness of the effect of antagonistic muscles on the hip loads is important because gait analysis only provides a reflection of the net agonist muscle activity but relative agonist/antagonist forces cannot be deduced. Variations in hip force during gait due to muscle activation differences could affect the long term outcome of THR surgery, which is an especially important consideration for the younger, more active patient.


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