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DECREASED KNEE ADDUCTION MOMENT DOES NOT GUARANTEE DECREASED MEDIAL CONTACT FORCE DURING GAIT

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INTRODUCTION

Medial compartment knee osteoarthritis (OA) plagues a large portion of the population [1]. The disease process is often initiated by changes in knee joint motions and loads, such as following anterior cruciate ligament or meniscal injury. Since overloading of the medial compartment in particular has been hypothesized to play a critical role, many treatment approaches have made reduction of medial contact force during gait their primary target.

Unfortunately, no accurate method currently exists for determining *in vivo* medial and lateral knee contact forces in individual patients. External measurements and dynamic analyses can determine the net forces and torques experienced by a joint, but knowledge of muscle and ligament forces is needed to determine contact forces accurately. Since contact force predictions from musculoskeletal computer models have yet to be thoroughly validated, researchers have proposed the external knee adduction moment as a surrogate measure for medial compartment load [2]. This moment normally exhibits two peaks during stance phase, with the first one typically being the largest. The value of the largest peak during stance phase has been shown to be highly correlated with disease severity [3] and rate of disease progression [4], while the instantaneous value during stance phase has been shown to be highly correlated with medial contact force measurements provided by an instrumented knee implant [5]. However, no study has shown that changes in the peak knee adduction moment are an accurate indicator of changes in peak medial contact force during stance phase.

This study uses gait data collected from a subject with a force-measuring knee replacement to determine whether changes in both peaks of the knee adduction moment curve are accurate indicators of corresponding changes in both peaks of the medial contact force curve. Changes in knee adduction moment and medial contact force peaks were achieved through the use of three different gait patterns. The results challenge the current hypothesis that reduction of the largest peak in the knee adduction moment curve necessarily means a reduction in the largest peak of the medial contact force curve.

METHODS

One patient with a force-measuring knee replacement (male, right knee, age 83, mass 68 kg, height 1.7 m, body mass index 23.5, neutral leg alignment) performed overground gait with simultaneous collection of internal knee contact force, external video motion, and external ground reaction data [6]. Institutional review board approval and informed consent were obtained. The implant utilized a custom tibial prosthesis instrumented with four uniaxial force transducers, a micro-transmitter, and an antenna, where the transducers measured compressive force at the four corners of the tibial tray. The subject performed five trials each for three different gait patterns: 1) the subject’s normal gait pattern (normal gait), 2) a modified gait pattern involving knee medialization during stance phase (medial thrust gait [6]), and 3) a modified gait pattern involving the use of bilateral hiking poles (walking pole gait). The two modified gait patterns were chosen for their potential to alter medial compartment contact force during stance phase. The subject performed all three gait patterns at his self-selected walking speed of 1.23 m/s.

The peak values of knee adduction moment and medial contact force during stance phase were calculated for each gait pattern, and changes relative to normal gait were analyzed statistically. Inverse dynamic knee loads were calculated using a patient-specific dynamic gait model developed using previously published methods [5]. Medial compartment contact force was calculated from the four implant load cell measurements using a previously validated regression equation [5]. Two peak values for the knee adduction moment and medial contact force were found by identifying the maximum value of each curve during the first and second half of stance phase. Changes in peak values for medial thrust and walking pole gait relative to normal gait were analyzed statistically using a two-tailed Mann-Whitney U test, which is the non-parametric equivalent to a two-tailed t-test. The level of statistical significant was set at 0.05. In addition, the ability of the knee adduction moment peaks to predict the peak values of medial contact force was investigated using linear regression analysis.

RESULTS

Reductions in peak knee adduction moment did not necessarily correspond to reductions in peak medial contact force (Table 1). During early stance phase, both modified gait patterns produced statistically significant reductions in peak knee adduction moment (Fig. 1, orange bars), whereas neither gait pattern produced a statistically significant change in medial contact force (Fig. 2, orange bars). In contrast, during late stance phase, only walking pole gait produced a statistically significant reduction in peak knee adduction moment (Fig. 1, blue bars), while both gait patterns produced statistically significant reductions in medial contact force (Fig. 2, blue bars). Regression analysis revealed that the first peak of the knee adduction moment curve was a poor predictor of the first peak in medial contact force (R^2 = 0.26), while the second peak of the adduction moment curve was a better predictor of the second peak in medial contact force (R^2 = 0.65).

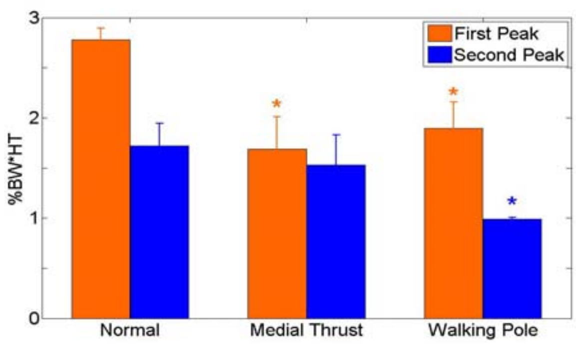

Fig. 1: Changes in knee adduction moment peaks. Star (*) denotes significant difference from normal trials.

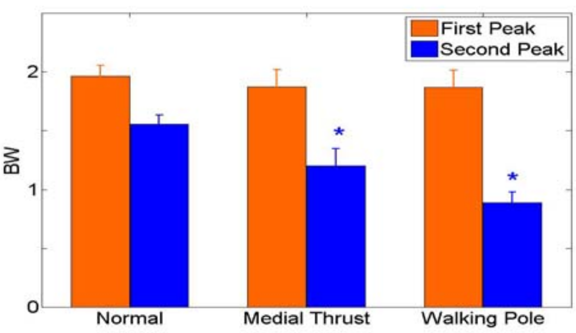

Fig. 2: Changes in medical contact force peaks. Star (*) denotes significant difference from normal trials.

DISCUSSION

This study evaluated the relationship between changes in both knee adduction moment peaks and changes in the corresponding medial contact force peaks. The availability of instrumented knee implant data collected simultaneously with the gait data provided a unique opportunity to investigate this relationship. The results suggest that reducing the peak knee adduction moment does not necessarily guarantee a reduction in corresponding peak medial contact force, at least for the first peak. They also suggest that other factors yet to be identified likely play an important role in determining medial contact force changes produced by a clinical intervention such as gait modification.

		Gait Pattern	
Quantity	**Peak**	Medial Thrust	Walking Pole
Knee Adduction Moment	First	39.3 ± 0.5	31.8 ± 0.4
	Second	9.7 ± 2.3	41.5 ± 0.1
Medial Contact Force	First	4.5 ± 0.3	4.6 ± 0.3
	Second	22.5 ± 0.5	42.6 ± 0.3

Table 1: Percent reductions (mean ± std) in knee adduction moment and medial contact force peaks relative to normal gait.

Identification of these other factors is difficult for the gait data used in this study. Since the first peak of the medial contact force curve was well fitted by the constant coefficient in the linear regression analysis, adding other covariates to the regression analysis produced little improvement in the fit. The best improvement was obtained when either the axial knee force from inverse dynamics or the vertical ground reaction force was added to the analysis, increasing R^2 from 0.26 to 0.40. Visual inspection of knee kinetic and kinematic changes revealed that for the two modified gait patterns, the subject increased his maximum knee flexion angle and peak knee extension torque during the first half of stance phase. Retrospective analysis revealed that these changes were statistically significant. Thus, it is possible that increased knee flexion during medial thrust and walking pole gait necessitated increased peak knee extension torque. This torque increase may have been the result of increased force generation by knee extensor muscles, which would tend to increase joint compression and offset the reduction produced by knee medialization or load transfer through the walking poles.

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