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RELATIONSHIP BETWEEN KNEE POWER AND MEDIAL KNEE JOINT LOADS IN KNEE OSTEOARTHRITIS

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SUMMARY

The progression of knee osteoarthritis (OA) is facilitated by excessive knee loading. Theoretical models of knee joint loads demonstrate that muscular contributions likely relate to the load transmitted through the knee. The relationship between knee loading with muscle strength and muscle power in people with knee OA remains unclear. The purpose of this study was to determine the extent to which knee strength and power explain variance in the knee adduction moment in 53 participants with clinical knee OA. To determine the knee adduction moment impulse, inverse dynamics was applied to motion capture and force data during level walking. Knee strength was the mean peak torque during five maximal isometric knee extensor efforts, normalized to body mass (Nm/kg). Knee power was the mean peak power produced during five isotonic knee extensor efforts. Knee strength was not related to the knee adduction moment impulse. After controlling for sex and BMI, knee extensor power explained a 10.3% of variance in the knee adduction moment impulse. Knee extensor power may have better potential than strength in explaining the knee adduction moment during gait because this measure reflects the ability to develop muscle force quickly in response to loading.

INTRODUCTION

The knee adduction moment (KAM), a measure of medial knee loading, and deficits in knee extensor function are risk factors for the progression of knee OA [1-4]. While modeling demonstrates the potential for knee muscles to influence knee loads and loading rates [5], knee extensor strength did not relate to impact loading in knee OA (n=204) [6]. Strengthening the knee extensors did not reduce the peak KAM in 54 women with knee OA [7]. Knee extensor strength may not be the best variable to represent muscle function in knee OA.

Muscle power, that is the rate of work performance, is a much better predictor of mobility performance than strength in healthy old adults [8]. However, the role of knee extensor power on gait mechanics has not been investigated in knee OA. The purpose of this study was to determine the extent to which knee extensor strength and power explain variance in the KAM in clinical knee OA. We hypothesized that both knee extensor strength and power would explain variance in the KAM during gait.

METHODS

Participants between the ages of 40-70 who met the American College of Rheumatology clinical criteria for knee OA were recruited. The KAM was calculated from three-dimensional motion data captured using Optotrak Certus position sensors (NDI, Waterloo, Canada) and force data collected using a synchronized floor-mounted force plate (AMTI, Watertown, MA, USA). Rigid, infrared marker clusters were secured to the sacrum, thigh, shank and foot of the study leg. Participants ambulated barefoot at self-selected speeds until five trials were captured. The KAM waveform was generated using inverse dynamics using commercial software (Visual 3D, C-Motion, Inc., Germantown, MD, USA). The mean non-normalized KAM impulse was used to reflect the total medial knee load encountered during gait.

Knee extensor strength and power were measured on an isokinetic dynamometer (Biodex Medical Systems, Shirley, NY, USA). To measure knee extensor strength, five maximal effort isometric knee extensor (MVIC) contractions were performed with the knee at 60°, where the peak torque value was normalized to body mass (Nm/kg). To measure knee extensor power, ten isotonic contractions with the resistance set at 25% of MVIC were performed as quickly as possible. The peak power values from the middle 5 contractions were averaged to represent knee extensor power (W). Potential covariates included age, sex, knee pain, gait speed and obesity. Knee pain was measured using the pain subscale of the Knee Injury and Osteoarthritis Outcome Score (KOOS-pain). Gait speed was measured during gait trials, and Body Mass Index (kg/m^2) was used as a measure of obesity.

First, relationships between the KAM impulse and each of the potential covariates were explored using Pearson correlation coefficients. Any variable that related significantly with the KAM impulse was then used in subsequent regression analyses. These regression analyses explored the relationship between the KAM impulse with each of knee extensor strength and power using two sequential forward linear regression models, after controlling for covariates.

RESULTS AND DISCUSSION

Fifty-three adults (61.6 ± 6.3 years, 11 men) participated (Table 1). The KAM impulse correlated with sex (r=-0.29, p<0.05), where men had greater KAM impulses than women (13.61±10.72, 8.82±4.86 respectively; $p<0.05$). The KAM impulse also correlated with BMI ($r=0.40$, $p<0.05$), and knee extensor power ($r=0.44$; $p<0.05$). Age, knee pain and gait speed did not correlate with KAM impulse ($p>0.05$) and were not included as covariates in the subsequent regression analyses.

Results of the regression analyses are shown in Table 2. Regression analysis between the KAM impulse and knee extensor strength showed that 24% of the variance in the KAM impulse was explained by the covariates in the model ($p=0.001$), not knee extensor strength ($p=0.40$). A second regression analysis showed that 35% of the variance in the KAM impulse was explained by the model ($p=0.01$), with knee extensor power contributing 10.3% ($p<0.05$).

Table 1: Descriptors of the knee OA participants (n=53).

	Mean (SD)
Age (y)	61.6 (6.3)
Body Mass (kg)	75.0 (16.2)
Height (m)	1.6 (0.1)
BMI (kg/m^2)	27.9 (5.6)
KOOS-pain (scale 0-100)	74.7 (17.3)
Gait Speed (m/s)	1.1 (0.3)
Knee Strength (Nm)	110.4 (47.5)
Knee Strength Normalized (Nm/kg)	1.5 (0.6)
Knee Power (W)	242.0 (140.1)
KAM Impulse (Nm•s)	9.8 (6.7)

This study demonstrated that knee extensor power was weakly related to medial compartment loading among participants with clinical knee OA. Knee extensor strength, on the other hand, was not related to the knee adduction moment. Compared to force alone (or "strength"), combining force production with speed in a measure of knee muscle power may better reflect the capacity of knee muscles to influence the mechanical loading environment of the knee.

Similar phenomena are established in healthy aging literature where muscle power was a stronger predictor of functional performance than strength [8]. In over 1400 elder participants, leg power described more of the variance than strength in the performance of important mobility tasks (gait speed, stair climb time), where poor muscle power was associated with a 2-3 fold greater risk than poor muscle strength in mobility problems [8]. In healthy old women, muscle power had stronger relationships with physical performance scores (jumping, leg press) than strength (r=0.67-0.75 and r=0.48-0.61, respectively; $p<0.01$) [9].

Little research has investigated muscle power in knee OA. Muscle power at lower loads and higher velocities was more predictive of self-reported function (Western Ontario and McMaster Osteoarthritis Index) than muscle strength in knee OA (n=40) [10]. Similar to the current study, Berger et al. used a multijoint dynamometer to measure knee extensor MVICs and isotonic power at 10, 20, 30, 40, and 50% of isometric MVIC [10]. In the current study we used one isotonic power level, set to 25% of MVIC. Berger found that power predicted a small proportion of the variance in self-reported function (20% MVIC, $r^2=0.13$, $p<0.05$; and 30% MVIC, $r^2=0.12$, $p<0.05$) [10]. Power at lower loads is a better predictor of function than isometric torque in disabled older adults [11] and elderly women [12].

CONCLUSIONS

Knee extensor power appears to be a better measure than knee strength in explaining variance in the KAM impulse during gait in clinical knee OA. Further work examining these relationships at different percentages of MVICs and in the flexor muscles would enhance our understanding of the role of knee power and loading in knee OA.

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Table 2: Sequential forward linear regression models of the Knee Adduction Moment Impulse. Model 1 incorporates knee extensor strength as a potential predictor. Model 2 incorporates knee extensor power as a potential predictor.

Independent variables	**Cumulative Adjusted R^2**	**Standardized β coefficient**	**p**
Model 1:			
1. Sex	0.068	-0.294	0.033
2. Sex + BMI	0.242	0.431	0.001
Model 2:			
1. Sex	0.068	-0.294	0.033
2. Sex + BMI	0.242	0.431	0.001
3. Sex + BMI + Knee Extensor Power	0.345	0.372	0.004